DECLARATION

I, Hikaru MORIOKA, 1-17, Uchiya 3-chome, Minami-ku, Saitama-shi, Saitama, Japan, do hereby declare that I am familiar with the English and Japanese Languages and that I believe the annexed is an accurate translation of the certified copy of the Japanese Patent Application No.2003-25496, filed on February 3, 2003.

This 15th day of November, 2004

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JAPANESE PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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【Name of Document】 Specification 1

【Name of Document】 Drawing 1

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【NEED FOR PROOF】 Necessary

【TITLE OF THE DOCUMENT】 SPECIFICATION

【TITLE OF THE INVENTION】 LENS BARREL

【CLAIMS】

1. A lens barrel comprising:

a front lens group, a middle lens group, a rear lens group and an exposure control component which are positioned on a photographing optical axis in a ready-to-photograph state of said lens barrel; and

an optical-element-accommodating ring member which accommodates said front lens group, said middle lens group, said rear lens group and said exposure control component in a retracted state of said lens barrel; and

at least two actuators for actuating said exposure control component,

wherein said photographing optical axis is parallel to an axis of said optical-element-accommodating ring member,

wherein, when said lens barrel changes from said ready-to-photograph state to said retracted state, said front lens group and said rear lens group are moved rearward while approaching each other along said photographing optical axis, said middle lens group is retracted to a radially retracted position on an opposite

side of said axis of said optical-element-accommodating ring member from said photographing optical axis, and said middle lens group is moved rearward along said photographing optical axis so that said middle lens group is positioned in an off-axis space radially outside an on-axis space in which said rear lens group is positioned,

wherein one of said two actuators is positioned inside said optical-element-accommodating ring member in a first space between an inner peripheral surface of said optical-element-accommodating ring member and an outer edge of said front lens group accommodated in said optical-element-accommodating ring member, and

wherein said the other of said two actuators is positioned inside said optical-element-accommodating ring member in a second space between an inner peripheral surface of said optical-element-accommodating ring member and an outer edge of said rear lens group accommodated in said optical-element-accommodating ring member, and is positioned outside a moving path of said middle lens group at an axial position different from an axial position of said one of said two actuators in said photographing optical axis direction.

2. The lens barrel according to claim 1, wherein said exposure control component and said two actuators are fundamental elements of a subassembly which is fixed to said optical-element-accommodating ring member.

3. The lens barrel according to claim 1 or 2, wherein said optical-element-accommodating ring member comprises an inner flange which projects radially inwards from said optical-element-accommodating ring member to limit movement of said exposure control component in said optical axis direction, said two actuators being positioned on opposite sides of said inner flange in said optical axis direction, respectively.

4. The lens barrel according to any one of the preceding claims 1 through 3, wherein said optical-element-accommodating ring member is movable linearly along said axis thereof without rotating,

wherein said middle lens group moves together with said optical-element-accommodating ring member in said optical axis direction, and

wherein said lens barrel further comprises an optical element retracting mechanism for retracting said middle lens group to said radially retracted position to be positioned in said off-axis space by a retracting movement of said optical-element-accommodating ring member when said lens barrel changes from said ready-to-photograph state to said retracted state.

5. The lens barrel according to claim 4, further comprising at least one rotatable ring which are positioned concentrically with said optical-element-accommodating ring member to move said

optical-element-accommodating ring member linearly along said axis thereof by a rotation of said rotatable ring.

6. The lens barrel according to any one of the preceding claims 1 through 5, further comprising an optical axis position adjustment device, positioned inside said optical-element-accommodating ring member, for adjusting the position of an optical axis of said middle lens group,

wherein said optical axis position adjustment device and said other of said two actuators are positioned on opposite sides of said axis of said optical-element-accommodating ring member, respectively.

7. The lens barrel according to any one of the preceding claims 1 through 6, wherein said exposure control component is positioned on said photographing optical axis between said front lens group and said middle lens group when said lens barrel is in said ready-to-photograph state, and

wherein said exposure control component is positioned on said photographing optical axis between said front lens group and said rear lens group when said lens barrel is in said retracted state.

8. The lens barrel according to any one of the preceding claims 1 through 7, wherein said exposure control component comprises a shutter and a diaphragm.

9. The lens barrel according to any one of the preceding claims 1 through 9, wherein said front lens group, said middle lens group, said rear lens group and said exposure control component are fundamental elements of a photographing optical system of a zoom lens incorporated in a camera.

【DETAILED DESCRIPTION OF THE INVENTION】

【0001】

【Technical Field】

The present invention relates to a retractable photographing lens barrel, the length of which is smaller in a retracted state than that in a ready-to-photograph state.

【0002】

【Prior Art and Problems Thereof】

Miniaturization of lens barrels incorporated in optical devices such as cameras has been in increasing demand. Above all, further miniaturization of retractable photographing lenses, specifically the length thereof in a non-operating state, has been in strong demand. To meet such demands, the inventor of the present invention has proposed a retractable photographing lens disclosed in Japanese Patent Application No.2002-44306 (not yet open to the public) in which an optical element of a photographing optical system is retracted to a position deviating from the photographing optical axis of the photographing optical

system, and at the same time, the optical element together with other optical elements of the photographing optical system is retracted along the optical axis of the photographing optical system when the photographing lens is fully retracted. The mechanism achieving such complicated operations of the optical elements is required to operate with a high degree of accuracy. In a photographing lens having such an optical element retracting mechanism, it is desired that each of the optical elements of the photographing optical system including the retractable optical element be placed in the lens barrel in a space-saving manner. However, it is difficult to place such optical elements in a space-saving manner when actuators for actuating exposure control components such as a shutter and an adjustable diaphragm are positioned in the vicinity of the retractable optical element.

【0003】

【Related Patent Document】

Japanese Patent Application No.2002-44306

【0004】

【Objective of the Invention】

An object of the present invention is to provide a photographing lens barrel which is capable of retracting an optical element of a photographing optical system to a position deviating from the photographing optical axis of the photographing optical system, wherein at least two

actuators for actuating exposure control components are placed in the lens barrel in a space-saving manner.

【0005】

【Summary of the Invention】

The present invention is characterized in that it includes: a front lens group, a middle lens group, a rear lens group and an exposure control component which are positioned on a photographing optical axis in a ready-to-photograph state of the lens barrel; and a ring member which accommodates the front lens group, the middle lens group, the rear lens group and the exposure control component in a retracted state of the lens barrel; and at least two actuators for actuating the exposure control component, wherein the photographing optical axis is parallel to an axis of the optical-element-accommodating ring member, wherein, when the lens barrel changes from the ready-to-photograph state to the retracted state, the front lens group and the rear lens group are moved rearward while approaching each other along the photographing optical axis, the middle lens group is retracted to a radially retracted position on an opposite side of the axis of the optical-element-accommodating ring member from the photographing optical axis, and the middle lens group is moved rearward along the photographing optical axis so that the middle lens group is positioned in an off-axis space radially outside an

on-axis space in which the rear lens group is positioned, wherein one of the two actuators is positioned inside the optical-element-accommodating ring member in a first space between an inner peripheral surface of the optical-element-accommodating ring member and an outer edge of the front lens group accommodated in the optical-element-accommodating ring member, and wherein the other of the two actuators is positioned inside the optical-element-accommodating ring member in a second space between an inner peripheral surface of the optical-element-accommodating ring member and an outer edge of the rear lens group accommodated in the optical-element-accommodating ring member, and is positioned outside a moving path of the middle lens group at an axial position different from an axial position of the one of the two actuators in the photographing optical axis direction.

【0006】

Preferably, the exposure control component and the two actuators are fundamental elements of a subassembly which is fixed to the optical-element-accommodating ring member.

【0007】

Preferably, the optical-element-accommodating ring member comprises an inner flange which projects radially inwards from the optical-element-accommodating ring member to limit movement of the exposure control

component in the optical axis direction, the two actuators being positioned on opposite sides of the inner flange in the optical axis direction, respectively.

【0008】

Preferably, the optical-element-accommodating ring member is movable linearly along the axis thereof without rotating, wherein the middle lens group moves together with the optical-element-accommodating ring member in the optical axis direction, and wherein the lens barrel further comprises an optical element retracting mechanism for retracting the middle lens group to the radially retracted position to be positioned in the off-axis space by a retracting movement of the optical-element-accommodating ring member when the lens barrel changes from the ready-to-photograph state to the retracted state. Preferably, the lens barrel further comprises at least one rotatable ring which are positioned concentrically with the optical-element-accommodating ring member to move the optical-element-accommodating ring member linearly along the axis thereof by a rotation of the rotatable ring.

【0009】

The lens barrel can be constructed in a space-efficient manner if the lens barrel further comprises an optical axis position adjustment device, positioned inside the optical-element-accommodating

ring member, for adjusting the position of an optical axis of the middle lens group, wherein the optical axis position adjustment device and the other of the two actuators are positioned on opposite sides of the axis of the optical-element-accommodating ring member, respectively.

【0010】

Preferably, the exposure control component is positioned, e.g., on the photographing optical axis between the front lens group and the middle lens group when the lens barrel is in the ready-to-photograph state, wherein the exposure control component is positioned on the photographing optical axis between the front lens group and the rear lens group when the lens barrel is in the retracted state.

【0011】

The exposure control component can be a shutter and a diaphragm. The present invention is ideally applied to a photographing optical system of a zoom lens incorporated in a camera.

【0012】

【Embodiments】

Firstly, the overall structure of an embodiment of a zoom lens 71 according to the present invention will be hereinafter described below with reference to Figures 1 through 19. This embodiment of the zoom lens 71 is incorporated in a digital camera 70, and is provided with

a photographing optical system consisting of a first lens group (front lens group) LG1, a shutter S, an adjustable diaphragm (exposure control component) A, a second lens group (intermediate lens group) LG2, a third lens group (rear lens group) LG3, a low-pass filter (and the like) LG4, and a solid-state image pick-up device (CCD) 60. "Z1" shown in the drawings designates the optical axis of the photographing optical system. The photographing optical axis Z1 is parallel to a lens barrel axis Z0 of the zoom lens 71, and is decentered with respect to the lens barrel axis Z0. In the following descriptions, the term "optical axis direction" means a direction parallel to the photographing optical axis Z1 unless there is a different explanatory note on the expression.

【0013】

As shown in Figures 6 and 7, the camera 70 is provided in the camera body 72 thereof with a stationary barrel 22 fixed to the camera body 72, and a CCD holder 21 fixed to a rear portion of the stationary barrel 22. The CCD image sensor 60 is mounted to the CCD holder 21 to be held thereby via a CCD base plate 62. The low-pass filter LG4 is held by the CCD holder 21 to be positioned in front of the solid-state image pick-up device 60 via a filter holder 73 and a sealing member 61.

【0014】

The zoom lens 71 is provided in the stationary barrel 22 with an AF lens frame (third lens frame which

supports and holds the third lens group LG3) 51 which is guided linearly in the optical axis direction without rotating about the photographing optical axis Z1. Specifically, the zoom lens 71 is provided with a pair of AF guide shafts 52 and 53 which extend parallel to the photographing optical axis Z1 to guide the AF lens frame 51 in the optical axis direction without rotating the AF lens frame 51 about the photographing optical axis Z1. Front and rear ends of each guide shaft of the pair of AF guide shafts 52 and 53 are fixed to the stationary barrel 22 and the CCD holder 21, respectively. The pair of AF guide shafts 52 and 53 are respectively fitted into a pair of guide holes 51a and 51b so that the AF lens frame 51 is slidable on the pair of AF guide shafts 52 and 53. In this particular embodiment, the AF guide shaft 52 serves as a main guide shaft, while the AF guide shaft 53 serves as a member for preventing the AF lens frame 51 from rotating. An AF motor 160 having a rotary drive shaft is threaded to serves as a feed screw shaft, and this rotary drive shaft is screwed through a screw hole formed on an AF nut 54 fixed to the AF lens frame 51. Due to this structure, rotating the rotary drive shaft forward and rearward causes the AF lens frame 51 to move forward and rearward in the optical axis direction by engagement of the rotary drive shaft (feed screw shaft) with the AF nut 54. The AF lens frame 51 is biased forward in the optical axis direction by an

AF-frame biasing spring 55.

【0015】

As shown in Figure 5, a zoom motor 150 and a reduction gear train box 74 are mounted on the stationary barrel 22. The reduction gear train box 74 contains a reduction gear train for transferring rotation of the zoom motor 150 to a zoom gear 28. The zoom gear 28 is pivoted to the stationary barrel 22 by a zoom gear shaft 29 which extends parallel to the photographing optical axis Z1. Rotations of the zoom motor 150 and the AF motor 160 are controlled by a control circuit 140 (see Figure 19) of the digital camera via a lens-drive-control FPC (flexible printed circuit) board 75 which is positioned on an outer peripheral surface of the stationary barrel 22.

【0016】

The stationary barrel 22 is provided on an inner peripheral surface thereof with a female helicoid 22a, a set of three linear guide grooves 22b, a set of three lead grooves 22c, and a set of three rotational sliding grooves 22d. The set of three linear guide grooves 22b extend parallel to the photographing optical axis Z1. The set of three lead grooves 22c extend parallel to the female helicoid 22a. The set of three rotational sliding grooves 22d are formed in the vicinity of a front end of the inner peripheral surface of the stationary barrel 22 to extend along a circumference of the

stationary barrel 22 to communicate the front ends of the set of three lead grooves 22c, respectively. The female helicoid 22a is not formed on that specific front area of the stationary barrel 22 on which the set of three rotational sliding grooves 22d are formed (see Figure 8).

【0017】

A helicoid ring 18 is provided on an outer peripheral surface thereof with a male helicoid 18a and a set of three rotational sliding projections 18b. The male helicoid 18a is engaged with the female helicoid 22a, and the set of three rotational sliding projections 18b are engaged in the set of three lead grooves 22c or the set of three rotational sliding grooves 22d, respectively (see Figures 4 and 9). The helicoid ring 18 is provided on threads of the male helicoid 18a with a spur gear portion 18c which is in mesh with the zoom gear 28. Therefore, when a rotation of the zoom gear 28 is transferred to the spur gear portion 18c, the helicoid ring 18 moves forward or rearward in the optical axis direction while rotating within a predetermined range in which the female helicoid 22a remains in mesh with the male helicoid 18a. A forward movement of the helicoid ring 18 beyond a predetermined point causes the spur gear portion 18c to be disengaged from the zoom gear 28 so that the helicoid ring 18 rotates about the lens barrel axis Z0 without moving in the optical axis direction relative to the zoom gear 28 by engagement of the set of three

rotational sliding projections 18b with the set of three rotational sliding grooves 22d. A circumferential space between two adjacent threads of the female helicoid 22a between which one of the three lead grooves 22c is positioned is greater than that between another two adjacent threads of the female helicoid 22a between which none of the three lead grooves 22c is positioned. The male helicoid 18a includes three wide threads 18a-W and twelve narrow threads. The three wide threads 18a-W are positioned behind the three rotational sliding projections 18b in the optical axis direction, respectively. The circumferential width of each of the three wide threads 18a-W is greater than that of each of the twelve narrow threads so that each of the three wide threads 18a-W can be positioned in the associated two adjacent threads of the female helicoid 22a between which one of the three lead grooves 22c is positioned (see Figures 8 and 9). The stationary barrel 22 is provided with a stop-member insertion hole 22e which radially penetrates one rotational sliding groove 22d and an outer peripheral surface of the stationary barrel 22. A barrel stop member 26 for preventing the helicoid ring 18 from rotating beyond a photographing range thereof is detachably attached to the stop-member insertion hole 22e.

【0018】

The helicoid ring 18 is provided, on an inner front

peripheral surface thereof at three different circumferential positions on the helicoid ring 18, with three rotation transfer recesses 18d (see Figures 4 and 10), while the third external barrel 15 is provided, at corresponding three different circumferential positions on the third external barrel (rotatable ring) 15, with three pairs of rotation transfer projections 15a (see Figures 4 and 11) which project rearward from the rear end of the third external barrel 15 to be inserted into the three rotation transfer recesses 18d from the front thereof, respectively. The three pairs of rotation transfer projections 15a and the three rotation transfer recesses 18d are movable relative to each other in a direction of the lens barrel axis Z0, and are not rotatable relative to each other about the lens barrel axis Z0. Namely, the helicoid ring 18 and the third external barrel 15 rotate in one piece. The helicoid ring 18 is provided on the three rotational sliding projections 18b with a set of three engaging recesses 18e which are formed on an inner peripheral surface of the helicoid ring 18. The third external barrel 15 is provided with a set of three engaging projections 15b which are engaged in the set of three engaging recesses 18e, respectively. The set of three engaging projections 15b, which are respectively engaged in the set of three engaging recesses 18e, are also engaged in the set of three rotational sliding grooves 22d at a time,

respectively, when the set of three rotational sliding projections 18b are engaged in the set of three rotational sliding grooves 22d (see an upper half of the zoom lens in Figure 6).

【0019】

The zoom lens 70 is provided between the third external barrel 15 and the helicoid ring 18 with three separating-direction biasing springs 25 which bias the third external barrel 15 and the helicoid ring 18 in opposite directions away from each other in the optical axis direction. The rear ends of the three separating-direction biasing springs 25 are respectively inserted into three spring insertion recesses 18f which are formed on the front end of the helicoid ring 18, while the front ends of the three separating-direction biasing springs 25 are respectively in pressing contact with three spring-engaging recesses 15c formed at the rear end of the third external barrel 15. Therefore, the set of three engaging projections 15b of the third external barrel 15 are respectively pressed against front surfaces in the set of three rotational sliding grooves 22d by the spring force of the three separating-direction biasing springs 25, while the set of three rotational sliding projections 18b of the helicoid ring 18 are respectively pressed against rotation guide surfaces in the set of three rotational sliding grooves 22d by the

spring force of the three separating-direction biasing springs 25. This removes backlash of the third external barrel 15 and the helicoid ring 18 with respect to the stationary barrel 22.

【0020】

The third external barrel 15 is provided on an inner peripheral surface thereof with a plurality of relative rotation guide projections 15d which are formed at different circumferential positions on the third external barrel 15, a circumferential groove 15e which extends in a circumferential direction about the lens barrel axis Z0, and a set of three rotation transfer grooves 15f which extend parallel to the lens barrel axis Z0 (see Figures 4 and 11). The circumferential positions of the three rotation transfer grooves 15f are formed to correspond to those of the three pairs of rotation transfer projections 15a, respectively. The rear end of each rotation transfer groove 15f is open at the rear end of the third external barrel 15. The helicoid ring 18 is provided on an inner peripheral surface thereof with a circumferential groove 18g which extends in a circumferential direction about the lens barrel axis Z0 (see Figures 4 and 10). The zoom lens is provided inside the third external barrel 15 and the helicoid ring 18 with a first linear guide ring 14. The first linear guide ring 14 is provided on an outer peripheral surface thereof with a set of three linear

guide projections 14a, a first plurality of relative rotation guide projections 14b, a second plurality of relative rotation guide projections 14c, and a circumferential groove 14d in this order from rear to front of the first linear guide ring 14 in the optical axis direction (see Figures 4 and 12). The set of three linear guide projections 14a project radially outwards. The first plurality of relative rotation guide projections 14b project radially outwards at different circumferential positions on the first linear guide ring 14, and the second plurality of relative rotation guide projections 14c project at different circumferential positions on the first linear guide ring 14. The circumferential groove 14d is an annular groove with its center on the lens barrel axis Z0. The first linear guide ring 14 is guided in the optical axis direction with respect to the stationary barrel 22 by engagement of the set of three linear guide projections 14a with the set of three linear guide grooves 22b, respectively. The third external barrel 15 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by both the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. The second plurality of relative rotation

guide projections 14c and the circumferential groove 15e are engaged with each other to be slightly movable relative to each other in the optical axis direction. Likewise, the plurality of relative rotation guide projections 15d and the circumferential groove 14d are engaged with each other to be slightly movable relative to each other in the optical axis direction. The helicoid ring 18 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g. The first plurality of relative rotation guide projections 14b and the circumferential groove 18g are engaged with each other to be slightly movable relative to each other in the optical axis direction.

【0021】

The first linear guide ring 14 is provided with a set of three guide slots 14e which radially penetrate the first linear guide ring 14. As shown in Figure 12, each guide slot 14e includes a front circumferential slot portion 14e-1, a rear circumferential slot portion 14e-2, and a lead slot portion 14e-3 which connects the front circumferential slot portion 14e-1 with the rear circumferential slot portion 14e-2. The front circumferential slot portion 14e-1 and the rear circumferential slot portion 14e-2 extend parallel to

each other in a circumferential direction of the first linear guide ring 14. The lead slot portion 14e-3 extends parallel to the threads of the female helicoid 22a. A set of three roller followers 32 fixed to an outer peripheral surface of a cam ring 11 at different circumferential positions thereon are engaged in the set of three guide lots 14e, respectively. Each roller follower 32 is fixed to the cam ring 11 by roller set screws 32a. The set of three roller followers 32 are further engaged in the set of three rotation transfer grooves 15f through the set of three guide lots 14e, respectively. A set of three roller pressing protrusions 17a protrude rearward from a roller-biasing spring 17 to be engaged in front portions of the set of three rotation transfer grooves 15f, respectively (see Figure 11). The set of three roller pressing protrusions 17a press the set of three roller followers 32 rearward to remove backlash between the set of three roller followers 32 and the set of three guide lots 14e when the set of three roller followers 32 are engaged in the front circumferential slot portions 14e-1 of the set of three guide lots 14e, respectively.

【0022】

Advancing operations of movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 will be understood with reference to the above described structure of the digital camera 70. Namely,

rotating the zoom gear 28 in a lens barrel advancing direction by the zoom motor 150 causes the helicoid ring 18 to move forward while rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with the male helicoid 18a. This rotation of the helicoid ring 18 causes the third external barrel 15 to move forward together with the helicoid ring 18 while rotating about the lens barrel axis Z0 together with the helicoid ring 18, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15 because each of the helicoid ring 18 and the third external barrel 15 is coupled to the first linear guide ring 14 to make respective relative rotations between the third external barrel 15 and the first linear guide ring 14 and between the helicoid ring 18 and the first linear guide ring 14 possible and to be movable together along a direction of a common rotational axis (i.e., the lens barrel axis Z0) due to the engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g, the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. Rotation of the third external barrel 15 is transferred to the cam ring 11 via the set of three rotation transfer grooves 15f and

the set of three roller followers 32, which are engaged in the set of three rotation transfer grooves 15f, respectively. Since the set of three roller followers 32 are also engaged in the set of three guide lots 14e, respectively, the cam ring 11 moves forward while rotating about the lens barrel axis Z0 relative to the first linear guide ring 14 in accordance with contours of the lead slot portions 14e-3 of the set of three guide lots 14e. Since the first linear guide ring 14 itself moves forward together with the third lens barrel 15 and the helicoid ring 18 as described above, the cam ring 11 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by engagement of the set of three roller followers 32 with the lead slot portions 14e-3 of the set of three guide lots 14e, respectively.

【0023】

The above described rotating-advancing operations are performed while the set of three rotational sliding projections 18b are moving in the set of three lead grooves 22c, respectively, when the male helicoid 18a and the female helicoid 22a are engaged with each other. When the helicoid ring 18 moves forward by a predetermined amount of movement, the male helicoid 18a and the female helicoid 22a are disengaged from each

other so that the set of three rotational sliding projections 18b move from the set of three lead grooves 22c to the set of three rotational sliding grooves 22d, respectively, while the set of three roller followers 32 enter the front circumferential slot portions 14e-1 of the set of three guide lots 14e, respectively. Since the helicoid ring 18 does not move in the optical axis direction relative to the stationary barrel 22 even if rotating upon the disengagement of the male helicoid 18a from the female helicoid 22a, the helicoid ring 18 and the third external barrel 15 rotate at respective axial fixed positions thereof without moving in the optical axis direction. In this state, since the first linear guide ring 14 stops while the set of three roller followers 32 have respectively moved into the front circumferential slot portions 14e-1, the cam ring 11 is not given any force making the cam ring 11 move forward. Consequently, the cam ring 11 only rotates at an axial fixed position in accordance with rotation of the third external barrel 15.

【0024】

Rotating the zoom gear 28 in a lens barrel retracting direction thereof causes the aforementioned movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 to operate in the reverse manner to the above described advancing operations. In this reverse operation, the above described fundamental

movable elements of the zoom lens 71 retract to their respective retracted positions shown in Figure 7 by rotation of the helicoid ring 18 until the set of three roller followers 32 enter the rear circumferential slot portions 14e-2 of the set of three guide lots 14e, respectively.

【0025】

The first linear guide ring 14 is provided on an inner peripheral surface thereof with a set of three pairs of first linear guide grooves 14f which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1, and a set of six second linear guide grooves 14g which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1. Each pair of first linear guide grooves 14f are position on the opposite sides of the associated linear guide groove 14g (every other linear guide groove 14g) in a circumferential direction of the first linear guide ring 14. A second linear guide ring 10 is provided on an outer edge thereof with a set of three bifurcated projections 10a. Each bifurcated projection 10a (see Figures 3 and 15) is provided at a radially outer end thereof with a pair of radial projections which are respectively engaged in the associated pair of first linear guide grooves 14f. On the other hand, a set of six linear guide projections 13a (see Figures 2 and 17) which are formed

on an outer peripheral surface of the second external barrel 13 at a rear end thereof to project radially outwards are engaged in the set of six second linear guide grooves 14g, respectively to be slidable therealong. Therefore, each of the second external barrel 13 and the second linear guide ring 10 is guided in the optical axis direction via the first linear guide ring 14.

【0026】

The second linear guide ring 10 serves as a linear guide member for guiding a second lens group moving frame 8 linearly without rotating the same, while the second external barrel 13 serves as a linear guide member for guiding the first external barrel 12 linearly without rotating the same. The second lens group moving frame 8 supports the second lens group LG2. The first external barrel 12 supports the first lens group LG1.

【0027】

The second linear guide ring 10 is provided on a ring portion 10b thereof with a set of three linear guide keys 10c which project forward (see Figures 3 and 15) from the ring portion 10b. As shown in Figures 6 and 7, an outer edge of the ring portion 10b is engaged in a circumferential groove 11e formed on an inner peripheral surface of the cam ring 11 at the rear end thereof to be rotatable about the lens barrel axis Z0 relative to the cam ring 11 and to be immovable relative to the cam ring 11 in the optical axis direction. The set of three

linear guide keys 10c project forward from the ring portion 10b to be positioned inside the cam ring 11. Opposite edges of each linear guide key 10c in a circumferential direction of the second linear guide ring 10 serve as parallel guide edges which are respectively engaged with circumferentially-opposed guide surfaces in an associated linear guide groove 8a of the second lens group moving frame 8, which is positioned in the cam ring 11 to be supported thereby, to guide the second lens group moving frame 8 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0. The linear guide grooves 8a are formed on an outer peripheral surface of the second lens group moving frame 8.

【0028】

The cam ring 11 is provided on an inner peripheral surface thereof with a plurality of inner cam grooves 11a. As shown in Figure 14, the plurality of inner cam grooves 11a are composed of a set of three front inner cam grooves 11a-1 formed at different circumferential positions, and a set of three rear inner cam grooves 11a-2 formed at different circumferential positions behind the set of three front inner cam grooves 11a-1. Although all the six cam grooves of the cam ring 11: the set of three front inner cam grooves 11a-1 and the set of three rear inner cam grooves 11a-2 trace six reference cam diagrams "α" having the same shape and size, respectively, the

area of each front inner cam groove 11a-1 on the reference cam diagram thereof is partly different from the area of the associated rear inner cam groove 11a-2 on the reference cam diagram thereof. Each reference cam diagram α represents the shape of each cam groove of the set of three front inner cam grooves 11a-1 and the set of three rear inner cam grooves 11a-2, and includes a lens-barrel operating section and a lens-barrel assembling/disassembling section, wherein the lens-barrel operating section consists of a zooming section and a lens-barrel retracting section. The lens-barrel operating section serves as a control section which controls movement of the second lens group moving frame 8 with respect to the cam ring 11, and which is to be distinguished from the lens-barrel assembling/disassembling section that is used only when the zoom lens 71 is assembled or disassembled. The zooming section serves as a control section which controls the movement of the second lens group moving frame 8 with respect to the cam ring 11, especially from a position of the second lens group moving frame 8 which corresponds to the wide-angle extremity of the zoom lens 71 to another position of the second lens group moving frame 8 which corresponds to the telephoto extremity of the zoom lens 71, and which is to be distinguished from the lens-barrel retracting section. If each front inner cam groove 11a-1 and the rear inner cam groove 11a-2

positioned therebehind in the optical axis direction are regarded as a pair, it can be said that the cam ring 11 is provided, at regular intervals in a circumferential direction of the cam ring 11, with three pairs of inner cam grooves 11a for guiding the second lens group LG2.

【0029】

The second lens group moving frame 8 is provided on an outer peripheral surface thereof with a plurality of cam followers 8b. The plurality of cam followers 8b include a set of three front cam followers 8b-1 which are formed at different circumferential positions to be respectively engaged in the set of three front inner cam grooves 11a-1, and a set of three rear cam followers 8b-2 which are formed at different circumferential positions behind the set of three front cam followers 8b-1 to be respectively engaged in the set of three rear inner cam grooves 11a-2.

【0030】

A rotation of the cam ring 11 causes the second lens group moving frame 8 to move in the optical axis direction in a predetermined moving manner in accordance with contours of the plurality of inner cam grooves 11a since the second lens group moving frame 8 is guided linearly in the optical axis direction without rotating via the second linear guide ring 10.

【0031】

The zoom lens 71 is provided inside the second lens

group moving frame 8 with a second lens frame (retractable movable member) 6. The second lens frame 6 is pivoted on a pivot shaft (pivot) 33 front and rear ends of which are supported by front and rear second lens frame support plates (optical axis position adjustment device) 36 and 37, respectively. The pair of second lens frame support plates 36 and 37 are fixed to the second lens group moving frame 8 by a support-plate set screw 66. The pivot shaft 33 is a predetermined distance away from the photographing optical axis Z1, and extend parallel to the photographing optical axis Z1. The second lens frame 6 is swingable about the pivot shaft 33 between a photographing position shown in Figure 6 where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 and a retracted position shown in Figure 7 where the optical axis of the second lens group LG2 is eccentric from the photographing optical axis Z1. A rotation limit pin 35 which determines the photographing position of the second lens frame 6 is mounted to the second lens group moving frame 8. The second lens frame 6 is biased to rotate in a direction to come into contact with the rotation limit pin 35 by a second-lens-frame returning spring 39. An axial-direction pressing spring 38 removes backlash of the second lens frame 6 in the optical axis direction.

【0032】

The second lens frame 6 moves together with the second lens group moving frame 8 in the optical axis direction. The CCD holder 21 is provided on a front surface thereof with a cam bar (optical element retracting mechanism) 21a which projects forward from the CCD holder 21to be engageable with the second lens frame 6 (see Figure 4). If the second lens group moving frame 8 moves rearward in a retracting direction to approach the CCD holder 21, a cam surface formed on a front end surface of the cam bar 21a comes into contact with the second lens frame 6 to rotate the second lens frame 6 to the retracted position. The structure retracting the second lens group LG2 will be discussed later.

【0033】

The structure supporting the first lens group LG1 will be discussed hereinafter. The second external barrel 13 is provided, on an inner peripheral surface thereof for supporting the first lens group LG1, with a set of three linear guide grooves 13b which are formed at different circumferential positions to extend in the optical axis direction. The first external barrel 12 is provided on an outer peripheral surface thereof at the rear end of the first external barrel 12 with a set of three engaging protrusions 12a which are slidably engaged in the set of three linear guide grooves 13b, respectively (see Figures 2, 17 and 18). Accordingly,

the first external barrel 12 is guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 via the first linear guide ring 14 and the second external barrel 13. The second external barrel 13 is further provided on an inner peripheral surface thereof in the vicinity of the rear end of the second external barrel 13 with a inner flange 13c which extends along a circumference of the second external barrel 13. The cam ring 11 is provided on an outer peripheral surface thereof a circumferential groove 11c in which the inner flange 13c is slidably engaged so that the cam ring 11 is rotatable about the lens barrel axis Z0 relative to the second external barrel 13 and so that the second external barrel 13 is immovable in the optical axis direction relative to the cam ring 11. On the other hand, the first external barrel 12 is provided on an inner peripheral surface thereof with a set of three rollers (cam followers) 31 which projects radially inwards, while the cam ring 11 is provided on an outer peripheral surface thereof with a set of three cam grooves 11b (for guiding the first lens group LG1) in which the set of three rollers 31 are slidably engaged, respectively.

【0034】

A first lens frame 1 is supported inside the first external barrel 12 by the first external barrel 12 via a first lens group adjustment ring 2. The first lens group LG1 is supported by the first lens frame 1 to be

fixed thereto. The first lens frame 1 is provided on an outer peripheral surface thereof with a male screw thread 1a, and the first lens group adjustment ring 2 is provided on an inner peripheral surface thereof with a female screw thread 2a which is engaged with the male screw thread 1a. The axis position of the first lens frame 1 relative to the first lens group adjustment ring 2 can be adjusted via the male screw thread and the female screw thread.

【0035】

The inner flange 12c of the first external barrel 12 is provided at radially opposite positions thereon with respect to the photographing optical axis Z1 with a pair of first guide grooves 12b, respectively, while the first lens group adjustment ring 2 is provided on an outer peripheral surface thereof with a corresponding pair of guide projections 2b (only one of them appears in Figure 2) which project radially outwards in opposite directions away from each other to be slidably fitted in the pair of first guide grooves 12b, respectively. The pair of first guide grooves 12b extend parallel to the photographing optical axis Z1 so that the combination of the first lens frame 1 and the first lens group adjustment ring 2 is movable in the optical axis direction with respect to the first external barrel 12 by engagement of the pair of guide projections 2b with the pair of first guide grooves 12b. The fixing ring 3 is fixed to the

first external barrel 12 by the two fixing-ring set screws 64 to close the front of the pair of guide projections 2b. The fixing ring 3 is provided at radially opposite positions thereon with respect to the photographing optical axis Z1 with a pair of spring receiving portions 3a so that a pair of biasing springs 24 for biasing the first lens group are installed in a compressed fashion between the pair of spring receiving portions 3a and the pair of guide projections 2b, respectively. Therefore, the first lens group adjustment ring 2 is biased rearward in the optical axis direction with respect to the first external barrel 12 by the spring force of the pair of biasing springs 24. The rear limit for the axial movement of the first lens group adjustment ring 2 with respect to the fixing ring 3 is determined by engagement of a set of four engaging projections 2c of the first lens group adjustment ring 2 with a front surface (which can be seen in Figure 2) of the fixing ring 3 (see an upper half of the zoom lens in Figure 6).

【0036】

The zoom lens 71 is provided between the first and second lens groups LG1 and LG2 with a shutter unit 76 including the shutter S and the adjustable diaphragm A. The shutter unit 76 is positioned in the second lens group moving frame 8 to be supported thereby. The aerial space between the shutter S and the second lens group LG2 is

fixed. Likewise, the aerial space between the diaphragm A and the second lens group LG2 is fixed. The zoom lens 71 is provided in front of the shutter unit 76 with a shutter actuator (not shown) for driving the shutter S, and is provided behind the shutter unit 76 with a diaphragm actuator (not shown) for driving the diaphragm A. An exposure control FPC (flexible printed circuit) board (flexible printed wiring board) 77 extends from the shutter unit 76 to establish electrical connection between the control circuit 140 and each of the shutter actuator and the diaphragm actuator.

【0037】

The zoom lens 71 is provided at the front end of the first external barrel 12 with a lens barrier mechanism which automatically closes a front end aperture of the zoom lens 71 when the zoom lens 71 is retracted into the camera body 72 to protect the photographing optical system, i.e. the first lens group LG1, from getting stains and scratches thereon when the digital camera 70 is not in use. The lens barrier mechanism is provided with a pair of barrier blades 104 and 105. The pair of barrier blades 104 and 105 are rotatable about two pivots projecting rearward therefrom to be positioned on radially opposite sides of the photographing optical axis Z1, respectively. The lens barrier mechanism is further provided with a pair of barrier blade biasing springs 106, a barrier blade drive ring 103, a drive ring

biasing spring 107 and a barrier blade holding plate 102. The pair of barrier blades 104 and 105 are biased to rotate in opposite directions to be closed by the pair of barrier blade biasing springs 106, respectively. The barrier blade drive ring 103 is rotatable about the lens barrel axis Z0, and is engaged with the pair of barrier blades 104 and 105 to open the pair of barrier blades 104 and 105 when driven to rotate in a predetermined rotational direction. The barrier blade drive ring 103 is biased to rotate in a barrier opening direction to open the pair of barrier blades 104 and 105 by the drive ring biasing spring 107. The barrier blade holding plate 102 is positioned between the barrier blade drive ring 103 and the pair of barrier blades 104 and 105. The spring force of the drive ring biasing spring 107 is greater than the spring force of the pair of barrier blade biasing springs 106 so that the barrier blade drive ring 103 is held in a specific rotational position thereof to open the pair of barrier blades 104 and 105 against the biasing force of the pair of barrier blade biasing springs 106 in the state shown in Figure 6 where the zoom lens 71 has been extended forward to a point in a zooming range (zooming operation performable range) where a zooming operation can be carried out. In the course of the retracting movement of the zoom lens 71 to the retracted position shown in Figure 10 from a position in the zooming range, the barrier blade drive ring 103 is forcefully

rotated in a barrier closing direction opposite to the aforementioned barrier opening direction by a barrier drive ring pressing surface 11d (see Figures 3 and 13) formed on the cam ring 11. This rotation of the barrier blade drive ring 103 causes the barrier blade drive ring 103 to be disengaged from the pair of barrier blades 104 and 105 so that the pair of barrier blades 104 and 105 are closed by the spring force of the pair of barrier blade biasing springs 106. The zoom lens 71 is provided immediately in front of the lens barrier mechanism with a lens barrier cover (decorative plate) 101 which covers the front of the lens barrier mechanism.

【0038】

A lens barrel advancing operation and a lens barrel retracting operation of the zoom lens 71 having the above described structure will be roughly discussed hereinafter with reference to Figures 6, 7 and 19. Figure 19 conceptually shows the relationship among fundamental elements of the zoom lens. In Figure 19, the symbols "(S)", "(L)", "(R)" and "(RL)" which are each appended as a suffix to the reference numeral of some elements of the zoom lens 71 indicate that the element is stationary, the element is solely movable linearly along a lens barrel axis Z0 without rotating about the lens barrel axis Z0, the element is rotatable about the lens barrel axis Z0 without moving along the lens barrel axis Z0, and the element is solely movable along the lens

barrel axis Z0 while rotating about the lens barrel axis Z0, respectively. Additionally, in Figure 19, each of the symbol "(R, RL)" and the symbol "(S, L) which is appended as a suffix to the reference numeral of some elements of the zoom lens 71 indicates that the operation of each of the elements changes between the advancing operation and the retracting operation.

【0039】

The stage at which the cam ring 11 is driven to advance from the retracted position to the position where the cam ring 11 rotates at the axial fixed position without moving in the optical axis direction has been discussed above, and will be briefly discussed hereinafter. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the zoom lens 71 is fully accommodated in the camera body 72 so that the front face of the zoom lens 71 is substantially flush with the front face of the camera body 72. Rotating the zoom gear 28 in the lens barrel advancing direction by the zoom motor 150 causes a combination of the helicoid ring 18 and the third external barrel 15 to move forward while rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with the male helicoid 18a, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15. At this time, the cam ring 11 which rotates by rotation of the third external barrel 15 moves

forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by a leading structure between the cam ring 11 and the first linear guide ring 14 (by engagement of the set of three roller followers 32 with the lead slot portions 14e-3 of the set of three guide lots 14e, respectively). Once the combination of the helicoid ring 18 and the third external barrel 15 advances to a predetermined point, the male helicoid 18a is disengaged from the female helicoid 22a while the set of three roller followers 32 are disengaged from the lead slot portions 14e-3 to enter the front circumferential slot portions 14e-1, respectively. Consequently, each of the helicoid ring 18 and the third external barrel 15 rotates about the lens barrel axis Z0 without moving in the optical axis direction.

【0040】

A rotation of the cam ring 11 causes the second lens group moving frame 8, which is positioned inside the cam ring 11, to move in the optical axis direction with respect to the cam ring 11 in a predetermined moving manner due to the engagement of the plurality of cam followers 8b with the plurality of cam grooves 11a, respectively. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the second

lens frame 6, which is positioned inside the second lens group moving frame 8, has rotated about the pivot shaft 33 to be held in the retracted position above the photographing optical axis Z1 by the cam bar 21a so that the optical axis of the second lens group LG2 moves from the photographing optical axis Z1 to a retracted optical axis Z2 positioned above the photographing optical axis Z1. In the course of movement of the second lens group moving frame 8 from the retracted position to a position in the zooming range, the second lens frame 6 is disengaged from the cam bar 21a to rotate about the pivot shaft 33 from the retracted position to the photographing position shown in Figure 6 where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 by the sprig force of the second-lens-frame returning spring 39. Thereafter, the second lens frame 6 remains to be held in the photographing position until when the zoom lens 71 is retracted into the camera body.

【0041】

In addition, a rotation of the cam ring 11 causes the first external barrel 12, which is positioned around the cam ring 11 and guided linearly in the optical axis direction without rotating, to move in the optical axis direction relative to the cam ring 11 in a predetermined moving manner due to engagement of the set of three rollers 31 with the set of three cam grooves 11b,

respectively.

【0042】

Accordingly, an axial position of the first lens group LG1 relative to a picture plane (a light-sensitive surface of the CCD image sensor 60) when the first lens group LG1 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the first external barrel 12 relative to the cam ring 11, while an axial position of the second lens group LG2 relative to the picture plane when the second lens group LG2 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the second lens group moving frame 8 relative to the cam ring 11. A zooming operation is carried out by moving the first and second lens groups LG1 and LG2 on the photographing optical axis Z1 while changing the space therebetween. When the zoom lens 71 is driven to advance from the retracted position shown in Figure 7, the zoom lens 71 firstly goes into a state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at wide-angle extremity. Subsequently, the zoom lens 71 goes into the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at telephoto extremity by a further

rotation of the zoom motor 150 in a lens barrel advancing direction thereof. As can be seen from Figure 9, the space between the first and second lens groups LG1 and LG2 when the zoom lens 71 is set at the wide-angle extremity is greater than that when the zoom lens 71 is set at the telephoto extremity. When the zoom lens 71 is set at the telephoto extremity as shown above the photographing lens axis Z1 in Figure 9, the first and second lens groups LG1 and LG2 have moved to approach each other to have some space therebetween which is smaller than the space in the zoom lens 71 set at the wide-angle extremity. This variation of the space between the first and second lens groups LG1 and LG2 for zooming operation is achieved by contours of the plurality of cam grooves 11a and the set of three cam grooves 11b. In the zooming range between the wide-angle extremity and the telephoto extremity, the cam ring 11, the third external barrel 15 and the helicoid ring 18 rotate at their respective axial fixed positions, i.e., without moving in the optical axis direction.

【0043】

In the zooming range, a focusing operation is carried out by moving the third lens group LG3 (the AF lens frame 51) along the photographing optical axis Z1 by rotation of the AF motor 160 in accordance with an object distance.

【0044】

Driving the zoom motor 150 in a lens barrel retracting direction causes the zoom lens 71 to operate in the reverse fashion to the above described advancing operation to fully retract the zoom lens 71 into the camera body 72 as shown in Figure 7. In the course of this retracting movement of the zoom lens 71, the second lens frame 6 rotates about the pivot shaft 33 to the retracted position by the cam bar 21a while moving rearward together with the second lens group moving frame 8. When the zoom lens 71 is fully retracted into the camera body 72, the second lens group LG2 is retracted into the space radially outside the space in which the third lens group LG3 and the low-pass filter LG4 are retracted as shown in Figure 10, i.e., the second lens group LG2 is into an axial range substantially identical to an axial range in the optical axis direction in which the third lens group LG3 and the low-pass filter LG4 are positioned. This structure of the camera 70 for retracting the second lens group LG2 in this manner reduces the length of the zoom lens 71 when the zoom lens 71 is fully retracted, thus making it possible to reduce the thickness of the camera body 72 in the horizontal direction as viewed in Figure 7.

【0045】

The digital camera 70 is provided with a zoom viewfinder the focal length of which varies to correspond to the focal length of the zoom lens 71. The zoom

viewfinder is given a driving force from the helicoid ring 18 by engagement of a viewfinder drive gear 30 with the spur gear portion 18c of the helicoid ring 18 so that the viewfinder drive gear 30 rotates by rotation of the helicoid ring 18 when the helicoid ring 18 rotates at the aforementioned fixed position in the zooming range. The zoom viewfinder is provided with a zoom type viewing optical system including an objective window plate 81a, a movable power-varying lens 81b, a movable power-varying lens 81c, a prism 81d, an eyepiece 81e and an eyepiece window plate 81f in this order from the object side. The focal length of the zoom viewfinder varies by moving the movable power-varying lens 81b and the movable power-varying lens 81c along an optical axis Z3 of the objective optical system of the zoom viewfinder. The optical axis Z3 is parallel to the photographing optical axis Z1. Respective support frames of the movable power-varying lens 81b and the movable power-varying lens 81c are linearly guided in a direction of the optical axis Z3 by a guide shaft 82, and each receive a drive force from a screw shaft extending parallel to the guide shaft 82. The digital camera 70 is provided between this screw shaft and the viewfinder drive gear 30 with a reduction gear train. A rotation of the viewfinder drive gear 30 causes the screw shaft to rotate to thereby move the movable power-varying lens 81b and the movable power-varying lens 81c forward and rearward. The above

described elements of the zoom viewfinder are put together to be prepared as a viewfinder unit (subassembly) 80 which is mounted on top of the stationary barrel 22.

【0046】

[DESCRIPTION OF THE STRUCTURE OF THE LENS BARREL RETRACTING MECHANISM]

The structure of the zoom lens 71 which accommodates the zoom lens 71 in the camera body 72 as shown in Figure 9, which incorporates the structure retracting the second lens group LG2 to the radially retracted position, will be hereinafter discussed in detail. In the following descriptions the terms "vertical direction" and "horizontal direction" mean the vertical direction and the horizontal direction as viewed from front or rear of the digital camera 70 such as the vertical direction of Figure 28 and the horizontal direction of Figure 29, respectively. In addition, the term "forward/backward direction" corresponds to the optical axis direction (i.e., a direction parallel to the photographing optical axis Z1).

【0047】

The second lens group LG2 is supported by the second lens group moving frame 8 via peripheral elements shown in Figures 20. The second lens frame 6 is provided with a cylindrical lens holder portion 6a, a pivoted cylinder 6b, a swing arm 6c and a stop arm portion 6e. The

cylindrical lens holder portion 6a supports the second lens group L2. The swing arm 6c extends in a radial direction of the cylindrical lens holder portion 6a to connect the cylindrical lens holder portion 6a to the pivoted cylinder 6b. The stop arm portion 6e is formed on the cylindrical lens holder portion 6a to extend in a direction away from the swing arm 6c. The pivoted cylinder 6b is provided with a pivot hole 6d extending in a direction parallel to the optical axis of the second lens group LG2. The pivoted cylinder 6b is provided at front and rear ends thereof, on front and rear sides of a portion of the pivoted cylinder 6b which is connected to the swing arm 6c, with a front spring support portion 6f and a rear spring support portion 6g, respectively. The front spring support portion 6f is provided, on an outer peripheral surface thereof in the vicinity of the front end of the front spring support portion 6f, with a front spring hold projection 6h. The rear spring support portion 6g is provided, on an outer peripheral surface thereof in the vicinity of the rear end of the rear spring support portion 6g, with a rear spring hold projection 6i. The pivoted cylinder 6b is provided on an outer peripheral surface thereof with a position control arm (spring hook portion) 6j extending in a direction away from the swing arm 6c. The position control arm 6j is provided with a first spring engaging hole 6k, and the swing arm 6c is provided with a second

spring engaging hole 6p (see Figures 35 through 37).

【0048】

The second lens frame 6 is provided with a rear projecting portion 6m which projects rearward in the optical axis direction from the swing arm 6c. The rear projecting portion 6m is provided at the rear end thereof with an AF-frame contacting surface 6n which lies in a plane orthogonal to the optical axis of the second lens group LG2. Although a second lens group holding lid 9 is fixed to the rear end of the cylindrical lens holder portion 6a to prevent the second lens group L2 from coming off the rear end of the cylindrical lens holder portion 6a as shown in Figures 45 and 46, the AF-frame contacting surface 6n is positioned behind the second lens group holding lid 9 in the optical axis direction. Namely, the AF-frame contacting surface 6n is positioned behind the rearmost position of the second lens group LG2 in the optical axis direction.

【0049】

The front second lens frame support plate 36 is a vertically-elongated narrow plate having a narrow width in horizontal direction. The front second lens frame support plate 36 is provided with a first vertically-elongated hole 36a, a pivot hole 36b, a cam-bar insertable hole 36c, a screw hole 36d, a horizontally-elongated hole 36e and a second vertically-elongated hole 36f, in this order from top to

bottom of the front second lens frame support plate 36. All of these holes 36a through 36f are through holes which penetrate the front second lens frame support plate 36 in the optical axis direction. The front second lens frame support plate 36 is provided on an outer edge thereof with a spring engaging recess 36g.

【0050】

Similar to the front second lens frame support plate 36, the rear second lens frame support plate 37 is also a vertically-elongated narrow plate having a narrow width in horizontal direction. The rear second lens frame support plate 37 is provided with a first vertically-elongated hole 37a, a pivot hole 37b, a cam-bar insertable hole 37c, a screw hole 37d, a horizontally-elongated hole 37e and a second vertically-elongated hole 37f, in this order from top to bottom of the rear second lens frame support plate 37. All of these holes 37a through 37f are through holes which penetrate the rear second lens frame support plate 37 in the optical axis direction. The front second lens frame support plate 37 is provided on an inner edge of the cam-bar insertable hole 37c with a guide key insertable recess 37g.

【0051】

The screw hole 36d of the front second lens frame support plate 36 and the screw hole 37d of the rear second lens frame support plate 37 have the same diameter so that

the set screw 66 can be screwed through the screw holes 36d and 37d. The set screw 66 is provided with a threaded shaft portion 66a and a head portion fixed to an end of the threaded shaft portion 66. The head portion is provided with a screwdriver engaging recess 66b into which the tip of a screwdriver serving as an adjusting tool can be inserted.

【0052】

The zoom lens 71 is provided between the front second lens frame support plate 36 and the rear second lens frame support plate 37 with a first eccentric shaft (optical axis position adjustment device) 34X. The first eccentric shaft 34X is provided with a large diameter portion 34X-a, and is provided at front and rear ends of the large diameter portion 34X-a with a front eccentric pin 34X-b and a rear eccentric pin 34X-c, respectively. The front eccentric pin 34X-b and the rear eccentric pin 34X-c have the same diameter and the common axis eccentric to the axis of the large diameter portion 34X-a. The front eccentric pin 34X-b is provided at the front end thereof with a screwdriver engaging recess 34X-d into which the tip of a screwdriver serving as an adjusting tool can be inserted. The zoom lens 71 is provided between the front second lens frame support plate 36 and the rear second lens frame support plate 37 with a second eccentric shaft (optical axis position adjustment device) 34Y. The structure of the

second eccentric shaft 34Y is the same as the structure of the first eccentric shaft 34X. Namely, the second eccentric shaft 34Y is provided with a large diameter portion 34Y-a, and is provided at front and rear ends of the large diameter portion 34Y-a with a front eccentric pin 34Y-b and a rear eccentric pin 34Y-c, respectively. The front eccentric pin 34Y-b and the rear eccentric pin 34Y-c have the same diameter and the common axis eccentric to the axis of the large diameter portion 34Y-a. The front eccentric pin 34Y-b is provided at the front end thereof with a recess 34Y-d into which the tip of a screwdriver serving as an adjusting tool can be inserted.

【0053】

The bore diameter of a rear end portion of the pivot hole 6d that penetrates the second lens frame 6 is increased to form a spring-accommodation large diameter hole (not shown) so that the compression coil spring 38 is accommodated in the spring-accommodation large diameter hole. The front torsion coil spring 39 and a rear torsion coil spring (optical element retracting mechanism) 40 are fitted on the front spring support portion 6f and the rear spring support portion 6g, respectively. The front torsion coil spring 39 is provided with a front spring end 39a and a rear spring end 39b, and the rear torsion coil spring 40 is provided with a front stationary spring end 40a and a rear movable

spring end 40b.

【0054】

The pivot shaft 33 is fitted in the pivot hole 6d from the rear end thereof so that the pivoted cylinder 6b of the second lens frame 6 can freely rotate on the pivot shaft 33 with no play in radial directions. The diameters of front and rear ends of the pivot shaft 33 correspond to the pivot hole 36b of the front second lens frame support plate 36 and the pivot hole 37b of the rear second lens frame support plate 37. In a state where the pivot shaft 33 is fitted in the pivot hole 6d, the axis of the pivot shaft 33 extends parallel to the optical axis of the second lens group LG2. The pivot shaft 33 is provided with a flange 33a which is inserted in the spring-accommodation large diameter hole (not shown) to contact with the rear end of the compression coil spring 38 that is accommodated in the spring-accommodation large diameter hole.

【0055】

As clearly shown in Figures 24 and 25, the second lens group moving frame 8 is an annular member having a through internal space 8n which penetrates the second lens group moving frame 8 in the optical axis direction. The second lens group moving frame 8 is provided, on an inner peripheral surface thereof at a substantially center thereof in the optical axis direction, with a central inner flange 8s. The inner edge of the central

inner flange 8s forms a second lens group traveling opening 8t which is elongated vertically. The shutter unit 76 is fixed to a front surface of the central inner flange 8s. The second lens group moving frame 8 is provided on an inner peripheral surface thereof behind the central inner flange 8s in the optical axis direction with a lens entering recess 8q which corresponds to the shape of an outer peripheral surface of the cylindrical lens holder portion 6a of the second lens frame 6 so that the cylindrical lens holder portion 6a can partly enter the lens entering recess 8q. The second lens group moving frame 8 is further provided on an inner peripheral surface thereof behind the central inner flange 8s with a stop arm portion entering recess 8r (see Figure 29) which is recessed radially outwards to correspond to the shape of an outer edge of the stop arm portion 6e of the second lens frame 6 so that the stop arm portion 6e can partly enter the stop arm portion entering recess 8r.

【0056】

As shown in Figures 24 and 25, the second lens group moving frame 8 is provided on a front end surface thereof (specifically, a right portion of the front end surface of the second lens group moving frame 8, on the right hand side of the second lens group traveling opening 8t, as viewed from front of the second lens group moving frame 8) with a front fixing surface 8c to which the front second lens frame support plate 36 is fixed. The front

fixing surface 8c is hatched in Figures 24 and 25 for the purpose of illustration. The front fixing surface 8c does not overlap the second lens group traveling opening 8t in the optical axis direction, and lies in a plane orthogonal to the optical axis of the second lens group LG2. The front fixing surface 8c is positioned in front of the shutter unit 76 in the optical axis direction. The front fixing surface 8c is formed to be exposed to the front of the second lens group moving frame 8. The second lens group moving frame 8 is provided at the front end thereof with a set of three extensions (partial cylinder portion) 8d extending forward in the optical axis direction. The set of three extensions 8d are formed as extensions of the second lens group moving frame 8 which extend forward from the front end of the second lens group moving frame 8. The set of three front cam followers 8b-1 are formed on outer peripheral surfaces of the set of three extensions 8d, respectively. The second lens group moving frame 8 is provided on a rear end surface thereof (specifically, a left portion of the rear end surface of the second lens group moving frame 8, on the left hand side of the second lens group traveling opening 8t, as viewed from rear of the second lens group moving frame 8) with a rear fixing surface 8e to which the rear second lens frame support plate 37 is fixed. The rear fixing surface 8e is positioned on the opposite side of the central inner flange 8s from the

front fixing surface 8c in the optical axis direction to be parallel to the front fixing surface 8c. The rear fixing surface 8e is formed as a part of the rear end surface of the second lens group moving frame 8; namely, the rear fixing surface 8e is flush with the rear end surface of the second lens group moving frame 8.

【0057】

The second lens group moving frame 8 is provided with a first eccentric shaft support hole 8f, a pivoted cylinder receiving hole 8g, a screw insertion hole 8h and a second eccentric shaft support hole 8i, in this order from top to bottom of the second lens group moving frame 8. All of these holes 8f, 8g, 8h and 8i are through holes which penetrate the second lens group moving frame 8 in the optical axis direction between the front fixing surface 8c and the rear fixing surface 8e. The second lens group moving frame 8 is provided on an inner peripheral surface thereon in the pivoted cylinder receiving hole 8g with a key way 8p extending in the optical axis direction. The key way 8p penetrates the second lens group moving frame 8 in the optical axis direction between the front fixing surface 8c and the rear fixing surface 8e. The diameter of the first eccentric shaft support hole 8f is determined so that the large diameter portion 34X-a is rotatably fitted in the first eccentric shaft support hole 8f, and the diameter of the second eccentric shaft support hole 8i is

determined so that the large diameter portion 34Y-a is rotatably fitted in the second eccentric shaft support hole 8i (see Figure 31). On the other hand, the diameter of the screw insertion hole 8h is determined so that the threaded shaft portion 66a is inserted in the screw insertion hole 8h with a substantial gap between the threaded shaft portion 66a and an inner peripheral surface of the screw insertion hole 8h (see Figure 31). The second lens group moving frame 8 is provided on the front fixing surface 8c and the rear fixing surface 8e with a front boss 8j and a rear boss 8k which project forward and rearward in the optical axis direction, respectively. The front boss 8j and the rear boss 8k have a common axis extending in the optical axis direction. The second lens group moving frame 8 is provided below the second lens group traveling opening 8t with a rotation limit shaft insertion hole 8m which penetrates the central inner flange 8s in the optical axis direction so that the rotation limit shaft 35 can be inserted into the second lens group traveling opening 8t.

【0058】

The rotation limit shaft 35 is provided with a large diameter portion 35a, and is provided at a rear end thereof with an eccentric pin 35b which projects rearward in the optical axis direction. The axis of the eccentric pin 35b is eccentric to the axis of the large diameter

portion 35. The rotation limit shaft 35 is provided at a front end thereof with a screwdriver engaging recess 35c into which the tip of a screwdriver serving as an adjusting tool can be inserted.

【0059】

Figures 26 through 29 show a state where the above described assemble parts are put together. A manner of putting the assembled parts together will be discussed hereinafter. First, the front torsion coil spring 39 and the rear torsion coil spring 40 are fixed to the second lens frame 6. At this time, a coil portion of the front torsion coil spring 39 is fitted on the front spring support portion 6f of the pivoted cylinder 6b with the rear spring end 39b being engaged with a portion of the second lens frame 6 between the pivoted cylinder 6b and the swing arm 6c (see Figure 22). The front spring end 39a of the front torsion coil spring 39 is not engaged with any part of the second lens frame 6. A coil portion of the rear torsion coil spring 40 is fitted on the rear spring support portion 6g of the pivoted cylinder 6b with the front stationary spring end 40a and the rear movable spring end 40b being inserted into the second spring engaging hole 6p of the swing arm 6c and the first spring engaging hole 6k of the position control arm 6j, respectively. The front stationary spring end 40a is fixed to the second spring engaging hole 6p while the rear movable spring end 40b is allowed to move in the first

spring engaging hole 6k in a range $\theta 1$ (theta 1) shown in Figure 37. In a free state, the rear torsion coil spring 40 is supported by the second lens frame 6 thereon with the front stationary spring end 40a and the rear movable spring end 40b being slightly pressed to move in opposite directions approaching each other so that the rear movable spring end 40b is in pressing contact with an inner wall surface of the position control arm 6j in the first spring engaging hole 6k (see Figure 37). The front torsion coil spring 39 is prevented from coming off the front spring support portion 6f from the front end thereof in the optical axis direction by the front spring hold projection 6h, while the rear torsion coil spring 40 is prevented from coming off the rear spring support portion 6g from the rear end thereof in the optical axis direction by the rear spring hold projection 6i.

【0060】

Aside from the installation of the front torsion coil spring 39 and the rear torsion coil spring 40, the pivot shaft 33 is inserted into the pivot hole 6d after the compression coil spring 38 is inserted into the spring-accommodation large diameter hole (not shown) that is formed in the rear end portion of the rear spring support portion 6g. At this time, the flange 33a of the pivot shaft 33 enters the rear spring support portion 6g to contact with the rear end of the compression coil spring 38. The axial length of the pivot shaft 33 is

greater than the axial length of the pivoted cylinder 6b so that the opposite ends of the pivot shaft 33 project from the front and rear ends of the pivoted cylinder 6b, respectively.

【0061】

Concurrent with the above described installation operations to the pivoted cylinder 6b, the first eccentric shaft 34X and the second eccentric shaft 34Y are inserted into the first eccentric shaft support hole 8f and the second eccentric shaft support hole 8i, respectively. The diameter of a front end portion of the large diameter portion 34X-a of the first eccentric shaft 34X is greater than the diameter of the remaining portion of the large diameter portion 34X-a, and the inner diameter of a corresponding front end portion of the first eccentric shaft support hole 8f is greater than the inner diameter of the remaining portion of the first eccentric shaft support hole 8f. Likewise, the diameter of a front end portion of the large diameter portion 34Y-a of the second eccentric shaft 34Y is greater than the diameter of the remaining portion of the large diameter portion 34Y-a, and the inner diameter of a corresponding front end portion of the second eccentric shaft support hole 8i is greater than the inner diameter of the remaining portion of the second eccentric shaft support hole 8i. Therefore, when inserted into the first eccentric shaft support hole 8f from the front end

thereof, the first eccentric shaft 34X is prevented from being further inserted into the first eccentric shaft support hole 8f upon the stepped portion between the large diameter portion 34X-a and the remaining portion of the first eccentric shaft 34X contacting with the bottom of the large-diameter front end portion of the first eccentric shaft support hole 8f as shown in Figure 31. Likewise, when inserted into the second eccentric shaft support hole 8i from the front end thereof, the second eccentric shaft 34Y is prevented from being further inserted into the second eccentric shaft support hole 8i upon the stepped portion between the large diameter portion 34Y-a and the remaining portion of the first eccentric shaft 34Y contacting with the bottom of the large-diameter front end portion of the second eccentric shaft support hole 8i as shown in Figure 31. In this state, the front eccentric pin 34X-b and the front eccentric pin 34Y-b project forward in the optical axis direction from the front fixing surface 8c while the rear eccentric pin 34X-c and the eccentric pin 34Y-c project rearward in the optical axis direction from the rear fixing surface 8e.

【0062】

Subsequently, the front second lens frame support plate 36 and the rear second lens frame support plate 37 are fixed to the front fixing surface 8c and the rear fixing surface 8e, respectively, while the front end of

the pivot shaft 33, which projects from the front end of the front spring support portion 6f of the pivoted cylinder 6b, is fitted into the pivot hole 36b of the front second lens frame support plate 36 and at the same time the rear end of the pivot shaft 33 is fitted into the pivot hole 37b of the rear second lens frame support plate 37. At this time, the front eccentric pin 34X-b, the front eccentric pin 34Y-b and the front boss 8j which project forward from the front fixing surface 8c are inserted into the first vertically-elongated hole 36a, the horizontally-elongated hole 36e and the second vertically-elongated hole 36f, respectively, and also the rear eccentric pin 34X-c, the rear eccentric pin 34Y-c and the rear boss 8k which project rearward from the rear fixing surface 8e are inserted into the first vertically-elongated hole 37a, the horizontally-elongated hole 37e and the second vertically-elongated hole 37f, respectively. The front eccentric pin 34X-b is movable and immovable in the first vertically-elongated hole 36a in the lengthwise direction and the widthwise direction thereof, respectively, the front eccentric pin 34Y-b is movable and immovable in the horizontally-elongated hole 36e in the lengthwise direction and the widthwise direction thereof, respectively, and the front boss 8j is movable and immovable in the second vertically-elongated hole 36f in the lengthwise direction and the widthwise

direction thereof, respectively. Likewise, the rear eccentric pin 34X-c is movable and immovable in the first vertically-elongated hole 37a in the lengthwise direction and the widthwise direction thereof, respectively, the rear eccentric pin 34Y-c is movable and immovable in the horizontally-elongated hole 37e in the lengthwise direction and the widthwise direction thereof, respectively, and the rear boss 8k is movable and immovable in the second vertically-elongated hole 37f in the lengthwise direction and the widthwise direction thereof, respectively.

【0063】

Lastly, the set screw 66 is screwed through the screw holes 36d and 37d to fix the front second lens frame support plate 36 and the rear second lens frame support plate 37 to the second lens group moving frame 8. At this time, the set screw 66 is screwed through firstly the screw hole 36d and subsequently the screw hole 37d through the screw insertion hole 8h. Screwing down the set screw 66 with the set screw 66 being engaged in the screw holes 36d and 37d causes the front second lens frame support plate 36 and the rear second lens frame support plate 37 to be pressed against the front fixing surface 8c and the rear fixing surface 8e, respectively, so that the front second lens frame support plate 36 and the rear second lens frame support plate 37 are fixed to the second lens group moving frame 8 with a spacing therebetween

which corresponds to the spacing between the front fixing surface 8c and the rear fixing surface 8e in the optical axis direction. As a result, the first eccentric shaft 34X and the second eccentric shaft 34Y are prevented from coming off the second lens group moving frame 8 by the front second lens frame support plate 36 and the rear second lens frame support plate 37. The front end of the pivoted cylinder 6b is pressed against the front second lens frame support plate 36 because the flange 33a of the pivot shaft 33 contacts with the rear second lens frame support plate 37 to be prevented from moving rearward beyond the rear second lens frame support plate 37 so that the pivot shaft 33 is biased forward in the optical axis direction by the spring force of the compression coil spring 38 which is in a compressed state. This maintains the position of the second lens frame 6 relative to the second lens group moving frame 8 in the optical axis direction. In a state where the rear second lens frame support plate 37 is fixed to the second lens group moving frame 8, the guide key insertable recess 37g communicates with the key way 8p in the optical axis direction (see Figure 30).

【0064】

After the front second lens frame support plate 36 is fixed to the second lens group moving frame 8, the front spring end 39a of the front torsion coil spring 39 is placed into the spring engaging recess 36g. The rear

spring end 39b of the front torsion coil spring 39 has been engaged with a portion of the second lens frame 6 between the pivoted cylinder 6b and the swing arm 6c as mentioned above. Placing the front spring end 39a into the spring engaging recess 36g causes the front torsion coil spring 39 to be twisted, thus causing the second lens frame 6 to be biased to rotate about the pivot shaft 33 in a counterclockwise direction as viewed from front of the second lens frame 6 (counterclockwise as viewed in Figure 32).

【0065】

Aside from the installation of the second lens frame 6, the rotation limit shaft 35 is inserted into the rotation limit shaft insertion hole 8m of the second lens group moving frame 8. An inner peripheral surface in the rotation limit shaft insertion hole 8m is formed to prevent the rotation limit shaft 35 from being further inserted into the rotation limit shaft insertion hole 8m from the position of the rotation limit shaft 35 shown in Figures 26 and 27. In this state where the rotation limit shaft 35 is properly inserted into the rotation limit shaft insertion hole 8m, the eccentric pin 35b of the rotation limit shaft 35 projects rearward from the rear end of the rotation limit shaft insertion hole 8m as shown in Figure 27.

【0066】

In a state where the second lens frame 6 is properly

mounted to the second lens group moving frame 8 in the above described manner, the second lens frame 6 can swing about the pivot shaft 33. The pivoted cylinder receiving hole 8g of the second lens group moving frame 8 is sufficiently large so that the pivoted cylinder 6b and the swing arm 6c may not interfere with the inner edge in the pivoted cylinder receiving hole 8g when the second lens frame 6 swings. Since the pivot shaft 33 extends parallel to the optical axis of the second lens group LG2, the second lens group LG2 swings about the pivot shaft 33 while the optical axis thereof remaining parallel to the photographing optical axis Z1 when the second lens frame 6 swings. One end of the range of rotation of the second lens frame 6 about the pivot shaft 33 is determined by the engagement of the tip of the stop arm portion 6e with the eccentric pin 35b. The front torsion coil spring 39 biases the second lens frame 6 to rotate in a direction to bring the tip of the stop arm portion 6e into contact with the eccentric pin 35b.

【0067】

Subsequently, the shutter unit 76 is fixed to the second lens group moving frame 8 to obtain a sub-assembly shown in Figures 26 through 29. As can be seen in Figures 26 through 28, the shutter unit 76 is fixed to the front of the central inner flange 8s. In this state where the shutter unit 76 is fixed to the front of the central inner flange 8s, the front fixing surface 8c is positioned in

front of the shutter S and the adjustable diaphragm A in the shutter unit 76 in the optical axis direction. A front portion of the cylindrical lens holder portion 6a of the second lens frame 6 is positioned in the second lens group traveling opening 8t, and is also positioned immediately behind the shutter unit 76 regardless of variation of the position of the second lens frame 6 relative to the second lens group moving frame 8.

【0068】

Although the second lens group moving frame 8 is provided at different circumferential positions thereon with three of the guide grooves 8a, one of the three guide grooves 8a: the wide guide groove 8a-W has a circumferential width greater than those of the other two guide grooves 8a so that the wide linear guide key 10c-W can be engaged in the wide guide groove 8a-W to be slidable therealong. The second lens group moving frame 8 is provided in the wide guide groove 8a-W with a radial recess in which the exposure control FPC board 77 can lie to be lead to the outside of the second lens group moving frame 8. Correspondingly, one of the three linear guide keys 10c: the wide linear guide key 10c-W has a circumferential width greater than those of the other two linear guide keys 10c to also serve as a support member for supporting the exposure control FPC board 77 used for exposure control. The wide linear guide key 10c-W is provided thereon with an FPC-passing through hole 10d

through which the exposure control FPC board 77 passes (see Figure 15).

【0069】

In a state where the second lens group moving frame 8 and the second linear guide ring 10 are coupled to each other, the exposure control FPC board 77 that extends from the shutter unit 76 is installed as shown in Figure 42. As described above, the wide linear guide key 10c-W of the second linear guide ring 10 is engaged in the wide guide groove 8a-W. The exposure control FPC board 77, the wide guide groove 8a-W and the wide linear guide key 10c-W in a radial direction of the lens barrel axis Z0 are positioned in the same position in a circumferential direction of the zoom lens 71. The exposure control FPC board 77 includes a first straight portion 77a, a U-shaped portion (loop-shaped turning portion) 77b, a second straight portion 77c and a third straight portion 77d in this order from the side of the shutter unit 76. A bend of the exposure control FPC board 77 is formed between the second straight portion 77c and the third straight portion 77d in the vicinity of the front end of the wide linear guide key 10c-W. From the side of the shutter unit 76, firstly the first straight portion 77a extends rearward in the optical axis direction from the shutter unit 76, and subsequently the exposure control FPC board 77 bends radially outwards to extend forward so that the loop-shaped turning portion 77b is formed in

the vicinity of the rear end of the second lens group moving frame 8 and so that the second straight portion 77c extends forward in the optical axis direction along an inner surface of the wide linear guide key 10c-W. Subsequently, the exposure control FPC board 77 bends radially outwards to extend rearward so that the third straight portion 77d extends rearward in the optical axis direction along an outer surface of the wide linear guide key 10c-W. Subsequently, the tip of the third straight portion 77d passes through the FPC-passing through hole 10d to extend rearward to be connected to the control circuit 140. The third straight portion 77d is partly fixed to the outer surface of the wide linear guide key 10c-W by a fixing means such as a double-faced tape so that the size of the loop-shaped turning portion 77c becomes variable in accordance with relative axial movement between the second lens group moving frame 8 and the second linear guide ring 10.

【0070】

As described above, the second lens group moving frame 8 which is prepared as a sub-assembly is moved in the optical axis direction by the cam ring 11, the AF lens frame 51 is positioned behind the second lens group moving frame 8 to be supported to be movable forward and rearward in the optical axis direction independently of movement of the cam ring 11, and the CCD holder 21 is fixed behind the AF lens frame 51.

【0071】

The AF lens frame 51, which is positioned behind the second lens group moving frame 8, is made of an opaque material, and is provided with a forwardly-projecting lens holder portion 51c, a first guide arm portion 51d and a second guide arm portion 51e as shown in Figures 38 through 41 and 44 through 47. The first guide arm portion 51d and the second guide arm portion 51e are positioned on radially opposite sides of the forwardly-projecting lens holder portion 51c. The forwardly-projecting lens holder portion 51c is positioned in front of the first guide arm portion 51d and the second guide arm portion 51e in the optical axis direction. The pair of guide holes 51a and 52a, in which the pair of AF guide shafts 52 and 53 are respectively fitted, are formed on the first guide arm portion 51d and the second guide arm portion 51e, respectively. The forwardly-projecting lens holder portion 51c is formed in a box shape including a substantially square-shaped front end surface (bottom surface) 51c1 and four side surfaces 51c3, 51c4, 51c5 and 51c6. The front end surface 51c1 lies in a plane orthogonal to the photographing optical axis Z1. The four side surfaces 51c3, 51c4, 51c5 and 51c6 extend rearward in a direction substantially parallel to the photographing optical axis Z1, toward the CCD image sensor 60, from the four sides of the front end surface 51c1. The rear end of the

forwardly-projecting lens holder portion 51c is formed as an open end which is open toward the low-pass filter LG4 the CCD image sensor 60. The forwardly-projecting lens holder portion 51c is provided on the front end surface 51c1 thereof with a circular opening 51c2 the center of which is coincident with the photographing optical axis Z1. The third lens group LG3 is positioned inside the circular opening 51c2. The first guide arm portion 51d and the second guide arm portion 51e extend from the forwardly-projecting lens holder portion 51c radially in opposite directions away from each other. More specifically, the first guide arm portion 51d extends from a corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 radially in a lower-rightward direction as viewed from front of the AF lens frame 51, while the second guide arm portion 51e extends from another corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c4 and 51c5 radially in a upper-leftward direction as viewed from front of the AF lens frame 51 as shown in Figure 47. As can be seen in Figures 45 and 46, the first guide arm portion 51d is fixed to the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 while the second guide arm portion 51e is fixed to the rear end of the corner of the forwardly-projecting lens holder portion 51c

between the two side surfaces 51c4 and 51c5.

【0072】

As shown in Figure 6, radially outwards ends of the first guide arm portion 51d and the second guide arm portion 51e are positioned radially outside a cylindrical portion 22f of the stationary barrel 22. The pair of guide holes 51a and 52a are respectively formed on radially outer ends of the first guide arm portion 51d and the second guide arm portion 51e which are positioned outside the cylindrical portion 22f. Accordingly, the AF guide shaft 52, which is fitted in the guide hole 51a and serves as a main guide shaft for guiding the AF lens frame 51 in the optical axis direction with a high positioning accuracy, is positioned outside the cylindrical portion 22f, while the AF guide shaft 53, which is loosely fitted in the guide hole 51b to serve as an auxiliary guide shaft for secondarily guiding the AF lens frame 51 in the optical axis direction is also positioned outside the cylindrical portion 22f. The cylindrical portion 22f is provided with two cutout portions 22g and 22h (see Figure 8) which are cut out along the AF guide shafts 52 and 53 to prevent the second guide arm portion 51e and the first guide arm portion 51d from interfering with the cylindrical portion 22f when the AF lens frame 51 moves in the optical axis direction. As shown in Figures 39 and 47, the pair of guide holes 51a and 52a are positioned on radially opposite sides of

the photographing optical axis Z1, and accordingly, the pair of AF guide shafts 52 and 53 are positioned on radially opposite sides of the photographing optical axis Z1.

【0073】

The AF lens frame 51 can move rearward in the optical axis direction to a point (rear limit for the axial movement of the AF lens frame 51) at which the first guide arm portion 51d and the second guide arm portion 51e come into contact with a stop surface 21b (see Figure 6) formed on a front surface of the CCD holder 21. In a state where the first guide arm portion 51d and the second guide arm portion 51e are in contact with the stop surface 21b, the front end of the position-control cam bar 21a, which projects forward from the CCD holder 21, is positioned in front of the AF lens frame 51 in the optical axis direction (see Figures 40 through 41). The cam-bar insertable hole 36c of the front second lens frame support plate 36 and the cam-bar insertable hole 37c of the rear second lens frame support plate 37 are positioned on an axis of the position-control cam bar 21a.

【0074】

As shown in Figures 21 and 22, the position-control cam bar 21a is provided at a front end thereof with a retracting cam surface 21c which is inclined with respect to the optical axis direction, and is further provided

along an inner side edge of the position-control cam bar 21a with a removed-position holding surface 21d which extends rearward from the retracting cam surface 21c in the optical axis direction. As can be seen in Figures 35 through 37, in which the position-control cam bar 21a is viewed from front thereof, the position-control cam bar 21a has a certain width in a substantially radial direction of the photographing optical axis Z1. The retracting cam surface 21c is formed as an inclined surface which is inclined forward in a direction from the radially inner side to the radially outer side of the position-control cam bar 21a (i.e., from a side closer to the photographing optical axis Z1 to a side farther from the photographing optical axis Z1), substantially along a widthwise direction of the retracting cam surface 21c. In Figures 35 through 37, the retracting cam surface 21c is hatched for the purpose of illustration. Moreover, the position-control cam bar 21a is formed so that an upper surface and a lower surface of the position-control cam bar 21a become a concave surface and a convex surface, respectively, to prevent the position-control cam bar 21a from interfering with the pivoted cylinder 6b of the second lens frame 6. In other words, the position-control cam bar 21a is formed to have an arc-shape cross section which is taken along a plane orthogonal to the optical axis direction and which is curved downwards to prevent the position-control cam bar

21a from interfering with the pivoted cylinder 6b. The position-control cam bar 21a is provided on a lower surface thereof with a guide key 21e which is elongated in the optical axis direction. The guide key 21e extends from the rear end of the position-control cam bar 21a to an intermediate point thereon behind the front end of the position-control cam bar 21a. Therefore, no part of the guide key 21e is formed on the position-control cam bar 21a in the vicinity of the front end thereof. The guide key 21e is formed to have a cross section shape allowed to enter the guide key insertable recess 37g.

【0075】

Operations of the second lens group LG2, the third lens group LG3 and other associated elements, which are supported by the above described accommodating structure including a structure retracting the second lens frame 6 to the radially retracted position thereof, will be hereinafter discussed. The position of the second lens group moving frame 8 with respect to the CCD holder 21 in the optical axis direction is determined by a combination of the axial movement of the cam ring 11 by the cam diagrams of the plurality of inner cam grooves 11a (11a-1 and 11a-2) and the axial movement of the cam ring 11 itself. In brief, the second lens group moving frame 8 is positioned farthest from the CCD holder 21 when the zoom lens 71 is set at about the wide-angle extremity as shown above the photographing optical axis Z1 in

Figure 9, and is positioned closest to the CCD holder 21 when the zoom lens 71 is in the retracted state as shown in Figure 7. The second lens frame 6 is retracted to the radially retracted position thereof by utilizing the retracting rearward movement of the second lens group moving frame 8 from the wide-angle extremity to the retracted position.

【0076】

In the zooming range between the wide-angle extremity and the telephoto extremity, the second lens frame 6 is held still at a fixed position by the engagement of the tip of the stop arm portion 6e with the eccentric pin 35b of the rotation limit shaft 35 as shown in Figure 6. At this time, the optical axis of the second lens group LG2 is coincident with the photographing optical axis Z1. When the second lens frame 6 is in a photographing position thereof as shown in Figure 29, a part of the position control arm 6j and the rear movable spring end 40b of the rear torsion coil spring 40 are exposed to the rear of the second lens group moving frame 8 through the cam-bar insertable hole 37c.

【0077】

Upon the main switch of the digital camera 70 being turned OFF in the ready-to-photograph state of the zoom lens 71, the control circuit 140 drives the AF motor 160 in the lens barrel retracting direction to move the AF lens frame 51 rearward, toward the CCD holder 21 to a

rearmost position (retracted position) thereof as shown in Figures 38, 40 and 41. The forwardly-projecting lens holder portion 51c holds the third lens group LG3 therein in the vicinity of the front end surface 51c1. The space immediately behind the third lens group LG3 is provided as an open space surrounded by the four side surfaces 51c3, 51c4, 51c5 and 51c6 so that the low-pass filter LG4 and the CCD image sensor 60, which are supported by the CCD holder 21 to project forward therefrom, can enter the space immediately behind the third lens group LG3 so as to reduce the space between the third lens group LG3 and the low-pass filter LG4 when the AF lens frame 51 is retracted to the rearmost position. In a state where the AF lens frame 51 is in the rearmost position as shown in Figure 7, the front end of the position-control cam bar 21a is positioned in front of the AF lens frame 51.

【0078】

Subsequently, the control circuit 140 drives the zoom motor 150 in the lens barrel retracting direction to perform the above described lens barrel retracting operation. Keep driving the zoom motor 150 in the lens barrel retracting direction beyond the wide-angle extremity of the zoom lens 71 causes the cam ring 11 to move rearward in the optical axis direction while rotating about the lens barrel axis Z0 due to engagement of the set of three roller followers 32 with the set of three lead slots 14e, respectively. As can be

understood from the relationship shown in Figure 14 between the plurality of inner cam grooves 11a and the plurality of cam followers 8b, even though the second lens group moving frame 8 is positioned closer to the front of the zoom lens 71 in the optical axis direction relative to the cam ring 11 when the zoom lens 71 is in the retracted position than that when the zoom lens 71 is in the wide-angle extremity, the second lens group moving frame 8 comes near the CCD holder 21 when the zoom lens 71 is in the retracted state because the amount or rearward movement of the cam ring 11 relative to the stationary barrel 22 is greater than the amount of forward movement of the second lens group moving frame 8 in the cam ring 11 relative to the cam ring 11 in the lens barrel retracting operation.

【0079】

A further retracting movement of the second lens group moving frame 8 together with the second lens frame 6 causes the front end of the position-control cam bar 21a to enter the cam-bar insertable hole 37c (see Figure 23). As described above, a part of the position control arm 6j and the rear movable spring end 40b of the rear torsion coil spring 40 are exposed to the rear of the second lens group moving frame 8 through the cam-bar insertable hole 37c. Figure 35 shows the positional relationship at this time among the position control arm 6j, the rear movable spring end 40b and the

position-control cam bar 21a, viewed from the front of the zoom lens 71. The rear movable spring end 40b is positioned closer to the position-control cam bar 21a than the position control arm 6j (except for a protrusion formed thereon for the formation of the first spring engaging hole 6k) in a radial direction of the photographing optical axis Z1. On the other hand, the retracting cam surface 21c is formed as an inclined surface which is inclined forward in a direction away from the photographing optical axis Z1. A frontmost portion of the retracting cam surface 21c is positioned immediately behind the rear movable spring end 40b of the rear torsion coil spring 40. A rearward movement of the second lens frame 6 together with the second lens group moving frame 8 toward the CCD holder 21 with the positional relationship shown in Figure 35 being maintained causes the retracting cam surface 21c to come into contact with the rear movable spring end 40b, not the position control arm 6j of the second lens frame 6. Figure 40 shows the position of the second lens frame 6 at the time immediately before the rear movable spring end 40b comes into contact with the retracting cam surface 21c.

【0080】

A further rearward movement of the second lens frame 6 with the rear movable spring end 40b remaining in contact with the retracting cam surface 21c causes the

rear movable spring end 40b to slide on the retracting cam surface 21c in a clockwise direction as viewed in Figure 35 in accordance with the shape of the retracting cam surface 21c. This clockwise rotation of the rear movable spring end 40b is transferred to the second lens group 6 via the front stationary spring end 40a. The spring force (rigidity) of the rear torsion coil spring 40 is predetermined to be capable of transferring a torque from the rear movable spring end 40b to the second lens group 6 via the front stationary spring end 40a without the front stationary spring end 40a and the rear movable spring end 40b being further pressed to move in opposite directions approaching each other than those shown in Figure 35. Namely, the resiliency of the rear torsion coil spring 40 is determined to be greater than that of the front torsion coil spring 39 at the time the front torsion coil spring 39 holds the second lens frame 6 in the photographing position.

【0081】

Upon receiving a turning force from the retracting cam surface 21c via the rear torsion coil spring 40, the second lens group 6 rotates about the pivot shaft 33 against the spring force of the front torsion coil spring 39 from the photographing position shown in Figure 29 toward the radially retracted position shown in Figure 30 in accordance with the retracting movement of the second lens group moving frame 8. With this rotation of

the second lens group 6, the rear movable spring end 40b of the rear torsion coil spring 40 slides on the retracting cam surface 21c from the position shown in Figure 35 to the position shown in Figure 36. Upon the second lens frame 6 rotating to the radially retracted position shown in Figure 30, the rear movable spring end 40b moves from the retracting cam surface 21c to the removed-position holding surface 21d to be engaged therewith. Thereafter, the second lens frame 6 is not rotated about the pivot shaft 33 in a direction to the radially retracted position by a retracting movement of the second lens group moving frame 8. In a state where the second lens frame 6 is held in the radially retracted position as shown in Figure 37, an outer peripheral portion of the cylindrical lens holder portion 6a enters the lens entering recess 8q while an outer edge of the stop arm portion 6e enters the stop arm portion entering recess 8r of the second lens group moving frame 8.

【0082】

After the second lens frame 6 reaches the radially retracted position, the second lens group moving frame 8 continues to move rearward until reaching the retracted position shown in Figure 7. During this rearward movement of the second lens group moving frame 8, the second lens group 6 moves rearward together with the second lens group moving frame 8 to the position shown in Figure 41 with the second lens group 6 held in the

radially retracted position, in which the rear movable spring end 40b remains in engaged with the retracting cam surface 21c. At this time, the front end of the position-control cam bar 21a projects forward from the cam-bar insertable hole 37c through the pivoted cylinder receiving hole 8g.

【0083】

As shown in Figures 7 and 41, in the retracted state of the zoom lens 71, the cylindrical lens holder portion 6a of the second lens frame 6 has moved into the space immediately above the forwardly-projecting lens holder portion 51c, the forwardly-projecting lens holder portion 51c has moved into that space in the second lens group moving frame 8 in which the second lens group LG2 is positioned in the ready-to-photograph state of the zoom lens 71, and the third lens group LG3 is positioned immediately behind the shutter unit 76. In addition, the low-pass filter LG4 and the CCD image sensor 60 have entered the forwardly-projecting lens holder portion 51c from the rear thereof by a rearward movement of the forwardly-projecting lens holder portion 51c, and accordingly, the space between the third lens group LG3 and the low-pass filter LG4 and also the space between the third lens group LG3 and the CCD image sensor 60 in the optical axis direction are smaller in the retracted state of the zoom lens 71 than those in the ready-to-photograph state of the zoom lens 71 as can be

seen by making a comparison between Figures 6 and 7. Namely, in the retracted state of the zoom lens 71, the second lens group LG2 is positioned in the space radially outside the space in which the third lens group LG3, the low-pass filter LG4 and the CCD image sensor 60 are positioned. In a conventional photographing lens barrel including a plurality of optical elements in which one or more movable optical elements thereof are moved only along a photographing optical axis, it is impossible to make the length of the photographing lens barrel smaller than the sum of the thicknesses of all the plurality of optical elements. However, according to the accommodating structure of the zoom lens 71, it is substantially unnecessary to secure any space for accommodating the second lens group LG2 on the photographing optical axis Z1. This makes it possible to make the length of the zoom lens 71 smaller than the sum of the thicknesses of all the plurality of optical elements of the zoom lens 71.

【0084】

In the present embodiment of the zoom lens, to make the second lens group LG2 retract to the position thereof shown in Figure 7, the AF lens frame 51 has various features in its shape and supporting structure that make it possible to retract the zoom lens 71 in the camera body 72 in a highly space-saving fashion. Namely, the AF guide shafts 52 and 53, which serves as a guide mechanism

for guiding the AF lens frame 51 in the optical axis direction, are positioned outside the cylindrical portion 22f, while the first guide arm portion 51d and the second guide arm portion 51e of the AF lens frame 51 that are guided by the AF guide shafts 52 and 53 are formed to extend from a rear end portion of the forwardly-projecting lens holder portion 51c. Due to structure of the AF lens frame 51, the space for not only the second lens frame 6 and the second lens group moving frame 8 but also the cam ring and the helicoid ring 18 that serve as rotating rings for moving the second lens frame 6 and the second lens group moving frame 8 can be secured inside the stationary barrel 22 without any of the second lens frame 6, the second lens group moving frame 8 and the cam ring and the helicoid ring 18 interfering with the AF guide shafts 52 and 53. In other words, according to such a structure of the AF lens frame 51, since the pair of AF guide shafts 52 and 53 can be disposed freely without being subject to constraints by moving parts positioned in the stationary barrel 22 such as the second lens frame 6, the effective length of each of the AF guide shafts 52 and 53 for guiding the AF lens frame 51 in the optical axis direction can be made long enough to guide the AF lens frame 51 in the optical axis direction with a high positioning accuracy. Additionally, an annular space which is surrounded by the outer peripheral surface of the forwardly-projecting

lens holder portion 51c, the first guide arm portion 51d, the second guide arm portion 51e and the inner peripheral surface of the stationary barrel 22 is secured due to the structure wherein the AF lens frame 51 is shaped so that the first guide arm portion 51d extends radially outwards from the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c3 and 51c6 and so that the second guide arm portion 51e extends radially outwards from the rear end of the corner of the forwardly-projecting lens holder portion 51c between the two side surfaces 51c4 and 51c5. This annular space is used to accommodate not only the second lens group LG2 but also rear end portions of annular members such as the first through third external barrels 12, 13 and 15 and the helicoid ring 18 to maximize the utilization of the internal space of the camera body 72. Moreover, the annular space contributes to a further retraction of the zoom lens 71 in the camera body 72.

【0085】

In addition, in the present embodiment of the zoom lens, the AF lens frame 51 is constructed so that the third lens group LG3 is supported by the forwardly-projecting lens holder portion 51c in a front end space thereof and so that the low-pass filter LG4 and the CCD image sensor 60 are accommodated in the space in the rear of the forwardly-projecting lens holder portion

51c in the retracted state of the zoom lens 71. This further maximize the utilization of the internal space of the zoom lens 71.

【0086】

In addition to the above, in the retracting operation of the zoom lens 71 from the wide-angle extremity, not only the second lens group moving frame 8 but also the first external barrel 12 that supports the first lens group LG1 retreat together with the cam ring 11, so that the relative space between the first lens group LG1 and the third lens group LG3 in the optical axis direction with the shutter unit 76 being positioned therebetween becomes small in the retracted state shown in Figure 7. Namely, in the present embodiment of the zoom lens 71, the length thereof in the optical axis direction from the first lens group LG1, which is positioned at the front end of the photographing optical system of the zoom lens 71, to the CCD 60, which is positioned at the rear end of the photographing optical system of the zoom lens 71 when the zoom lens 71 is in the retracted state is extremely reduced as compared with the length of a conventional similar type of lens barrel. The first lens frame 1 is provided at the rear end thereof with a contacting portion 1b (see Figures 6 and 7) which projects rearward beyond the rearmost portion of the first lens group LG1 to be capable of contacting with the shutter unit 76 to prevent the first lens group LG1 from

contacting with the shutter unit 76.

【0087】

Upon the main switch of the digital camera 70 being turned ON in the retracted state of the zoom lens 71, the control circuit 140 drives the AF motor 160 in the lens barrel advancing direction so that the above described moving parts operate in the reverse fashion to the above described retracting operations. The cam ring 11 advances while rotating relative to the first linear guide ring 14 and at the same time the second lens group moving frame 8 and the first external barrel 12 advance together with the cam ring 11 without rotating relative to the first linear guide ring 14. At an initial stage of the advancement of the second lens group moving frame 8, the second lens frame 6 remains in the radially retracted position since the rear movable spring end 40b is still engaged with the removed-position holding surface 21d. A further forward movement of the second lens group moving frame 8 causes the rear movable spring end 40b to firstly reach the front end of the position-control cam bar 21a and subsequently be disengaged from the removed-position holding surface 21d to be engaged with the retracting cam surface 21c as shown in Figure 37. At this stage, the cylindrical lens holder portion 6a of the second lens frame 6 has moved ahead of the forwardly-projecting lens holder portion 51c in the optical axis direction, so that the cylindrical lens

holder portion 6a does not interfere with the forwardly-projecting lens holder portion 51c even if the second lens frame 6 commences to rotate about the pivot shaft 33 in a direction to the photographing position. A further forward movement of the second lens group moving frame 8 causes the rear movable spring end 40b to slide on the retracting cam surface 21c so that the second lens frame 6 starts rotating from the radially retracted position to the photographing position by the spring force of the front torsion coil spring 39.

【0088】

A further forward movement of the second lens group moving frame 8 firstly causes the rear movable spring end 40b to keep sliding on the retracting cam surface 21c in a direction away from the removed-position holding surface 21d, and subsequently causes the rear movable spring end 40b to be disengaged from the retracting cam surface 21c upon the rear movable spring end 40b moving to a predetermined point on the retracting cam surface 21c. As a result, the second lens frame 6 becomes totally free from the constraint of the position-control cam bar 21a. Consequently, the second lens frame 6 is held in the photographing position with the tip of the stop arm portion 6e being in pressing contact with the eccentric pin 35b of the rotation limit shaft 35 by the spring force of the front torsion coil spring 39. Namely, the optical axis of the second lens group LG2

coincides with the photographing optical axis Z1. The second lens frame 6 finishes rotating from the radially retracted position to the photographing position by the time the zoom lens 71 has been extended to the wide-angle extremity.

【0089】

Although the AF lens frame 51 moves forward from its rearmost position when the zoom lens 71 changes from the retracted state to the ready-to-photograph state, the forwardly-projecting lens holder portion 51c still covers the front of the low-pass filter LG4 and the CCD image sensor 60 even in the ready-to-photograph state shown in Figure 6 so that the front end surface 51c1 and the four side surfaces 51c3, 51c4, 51c5 and 51c6 can prevent unnecessary light from being incident on the low-pass filter LG4 and the CCD image sensor 60 through any part other than the third lens group LG3. Accordingly, the forwardly-projecting lens holder portion 51c of the AF lens frame 51 serves as not only a member for supporting the third lens group LG3 but also a member for accommodating the low-pass filter LG4 and the CCD 60 in the retracted state of the zoom lens 71 and also a light shield member for preventing unnecessary light from being incident on the low-pass filter LG4 and the CCD image sensor 60.

【0090】

In general, a structure supporting a movable lens

group of a photographing lens system must be precise not to deteriorate the optical performance of the photographing lens system. In the present embodiment of the zoom lens, each of the second lens frame 6 and the pivot shaft 33, in particular, is required to have a high accuracy which is several orders of magnitude higher than those of simple movable elements since the second lens group LG2 is driven to not only move along the photographing optical axis Z1 but also rotate to retract to the radially retracted position. For instance, in a conventional lens barrel, if a pivot shaft corresponding to the pivot shaft 33 is intended to be disposed in an annular member in which exposure control devices such as the shutter S and the adjustable diaphragm A are included, the pivot shaft can be disposed only in front of or behind the exposure control devices. This may limit the length of the pivot shaft or may make the pivot shaft as a cantilever type pivot shaft. Nevertheless, since it is necessary to secure a minimum clearance allowing the pivot shaft (such as the pivot shaft 33) and a through hole (such as the pivot hole 6d) into which the pivot shaft is fitted to rotate relative to each other, such a clearance may cause the axis of the through hole to tilt relative to the axis of the pivot shaft if the pivot shaft is a short shaft or a cantilever pivot shaft. Even if within tolerance in a conventional lens supporting structure, such a tilt must be prevented from

occurring in the present embodiment of the zoom lens because each of the second lens frame 6 and the pivot shaft 33 is required to have a very high accuracy.

【0091】

In the above described retracting structure, since it can be seen in Figure 31 that the front second lens frame support plate 36 and the rear second lens frame support plate 37 are respectively fixed to the front fixing surface 8c and the rear fixing surface 8e, which are respectively positioned on front and rear of the shutter unit 76 in the optical axis direction, and that the pivot shaft 33 is disposed to extend between the front second lens frame support plate 36 and the rear second lens frame support plate 37, both the front end and the rear end of the pivot shaft 33 are supported by the front second lens frame support plate 36 and the rear second lens frame support plate 37, respectively. Accordingly, the axis of the pivot shaft 33 does not easily tilt. Moreover, the pivot shaft 33 can be lengthen regardless of the shutter unit 76 (without interfering with the shutter unit 76) since the front second lens frame support plate 36, the rear second lens frame support plate 37 and the pivoted cylinder receiving hole 8g, which serve as fundamental elements of the structure supporting the pivot shaft 33, are positioned not to overlap the shutter unit 76. In fact, the pivot shaft 33 is elongated so that the length thereof becomes

close to the length of the second lens group moving frame 8 in the optical axis direction. In accordance with the length of the pivot shaft 33, the pivoted cylinder 6b is elongated in the optical axis direction. Namely, a wide range of engagement in the axial direction is secured between the pivoted cylinder 6b and the pivot shaft 33. With this structure, there is little possibility of the second lens frame 6 from tilting with respect to the pivot shaft 33, which makes it possible to rotate the second lens frame 6 about the pivot shaft 33 with a high degree of positioning accuracy.

【0092】

The front boss 8j and the rear boss 8k that project from the front fixing surface 8c and the rear fixing surface 8e determine the position of the front second lens frame support plate 36 and the position of the rear second lens frame support plate 37, respectively, and the front and rear second lens frame support plates 36 and 37 are firmly fixed to the second lens group moving frame 8 by the common set screw 66. With this structure, the front and rear second lens frame support plates 36 and 37 are positioned relative to the second lens group moving frame 8 with a high degree of positioning accuracy. Therefore, also the pivot pin 33 is positioned relative to the second lens group moving frame 8 with a high degree of positioning accuracy.

【0093】

In the present embodiment of the zoom lens, the set of three extensions 8d are formed on the front end surface of the second lens group moving frame 8 in front of the front fixing surface 8c, whereas the rear fixing surface 8e is flush with the rear end surface of the second lens group moving frame 8. Namely, the front fixing surface 8c is not formed on the frontmost end surface of the second lens group moving frame 8. However, if the second lens group moving frame 8 is formed as a simple cylindrical member having no projections such as the set of three extensions 8d, the front and rear second lens frame support plates 36 and 37 can be fixed to frontmost and rearmost end surfaces of the simple cylindrical member, respectively.

【0094】

In the above described retracting structure, if the range of movement of the second lens group moving frame 8 in the optical axis direction from the position corresponding to the wide-angle extremity to the retracted position is fully used to rotate the second lens frame 6 about the pivot shaft 33 from the photographing position to the radially retracted position, the second lens frame 6 will interfere with the forwardly-projecting lens holder portion 51c of the AF lens frame 51 on the way to the radially retracted position. To prevent this problem from occurring, in the above described retracting structure, the second

lens frame 6 finishes rotating to the radially retracted position within an axial range of movement sufficiently shorter than the range of movement of the second lens group moving frame 8 in the optical axis direction and subsequently the cylindrical lens holder portion 6a of the second lens frame 6 moves rearward in parallel in the optical axis direction to the space immediately above the forwardly-projecting lens holder portion 51c. Therefore, the space for the parallel displacement of the cylindrical lens holder portion 6a to the space immediately above the forwardly-projecting lens holder portion 51c must be secured in the zoom lens 71. In order for the second lens frame 8 to secure a sufficient range of rotation from the photographing position to the radially retracted position within a short range of movement in the optical axis direction, it is necessary to increase the inclination of the retracting cam surface 21c, that is formed on the front end of the position-control cam bar 21a of the CCD holder 21, with respect to the direction of movement of the second lens group moving frame 8, i.e., with respect to the optical axis direction. While the retracting cam surface 21c that is formed in such a manner presses the rear movable spring end 40b, a great reaction force is exerted on the position-control cam bar 21a and the second lens group moving frame 8; such a reaction force is greater than that in the case where a cam surface the inclination of which

with respect to the direction of movement of the second lens group moving frame 8 is small presses the rear movable spring end 40b.

【0095】

The position-control cam bar 21a is a fixed member just like the stationary barrel 22, whereas the second lens group moving frame 8 is a linearly movable member; the second lens group moving frame 8 is guided linearly without rotating about the lens barrel axis Z0 indirectly by the stationary barrel 22 via such intermediate members as the first and second linear guide rings 14 and 10, not directly by the stationary barrel 22 as shown in Figure 19. A clearance exits in each of the following two engagements: the engagement of the second lens group moving frame 8 with the second linear guide ring 10 and the engagement of the second linear guide ring 10 with the second linear guide ring 14. Due to this reason, it has to be taken into account that such clearances may cause the second lens group moving frame 8 and the CCD holder 21 to become misaligned in the optical axis direction to thereby exert an averse effect on the retracting operation for the second lens frame 6 from the photographing position to the radially retracted position if a great reaction force is exerted on the position-control cam bar 21a and the second lens group moving frame 8. For instance, if the second lens frame 6 rotates beyond an original radial-outer limit thereof

(see Figure 30) for the rotational movement of the second lens frame 6 about the pivot shaft 33 when rotated from the photographing position to the radially retracted position, the cylindrical lens holder portion 6a may interfere with an inner peripheral surface of the second lens group moving frame 8. Likewise, if the second lens frame 6 stops rotating before the original radial-outer limit when rotated from the photographing position to the radially retracted position, i.e., if the second lens frame 6 does not rotate to the original radial-outer limit when rotated from the photographing position to the radially retracted position, the cylindrical lens holder portion 6a may interfere with the AF lens frame 51 and others.

【0096】

The position-control cam bar 21a of the second lens group moving frame 8 and the CCD holder 21 are prevented from being misaligned in the optical axis direction by inserting the guide key 21e into the guide key insertable recess 37g to hold the second lens frame 6 precisely in the radially retracted position when the second lens frame 6 rotates from the photographing position to the radially retracted position (see Figure 24). Specifically, when the second lens group moving frame 8 is in the process of retracting toward the retracted position with the second lens frame 6 having been held in the radially retracted position by the engagement of

the rear movable spring end 40b of the rear torsion coil spring 40 with the removed-position holding surface 21d, the guide key 21e enters the key way 8p of the second lens group moving frame 8 from the rear end thereof through the guide key insertable recess 37g. Since the guide key 21e and the key way 8p are an elongated projection and an elongated groove which extend in the optical axis direction, the guide key 21e is freely movable relative to the key way 8p in the optical axis direction and prevented from moving in a widthwise direction of the key way 8p when the guide key 21e is engaged in the key way 8p. Due to this structure, even if a reaction force is exerted on the second lens group moving frame 8 while the retracting cam surface 21c presses the rear movable spring end 40b, the engagement of the guide key 21e with the key way 8p prevents the second lens group moving frame 8 and the position-control cam bar 21a from being misaligned in the optical axis direction. Consequently, the second lens frame 6 is held precisely in the radially retracted position when the second lens frame 6 rotates from the photographing position to the radially retracted position.

【0097】

Although the guide key 21e commences to be engaged in the key way 8p after the second lens frame 6 has been rotated to the radially retracted position in the present embodiment of the zoom lens, the guide key 21e can

commence to be engaged in the key way 8p before the second lens frame 6 has been rotated to the radially retracted position in the present embodiment of the zoom lens or during the retracting movement of the second lens frame 6 toward the radially retracted position. In short, the second lens group moving frame 8 and the position-control cam bar 21a have only to be precisely aligned in the optical axis direction at the time when the second lens frame 6 is held in the radially retracted position after all. The timing of commencement of the engagement between the guide key 21e with the key way 8p can be freely determined by, e.g., changing the axial range of formation of the guide key 21e in the optical axis direction.

【0098】

It is possible that the guide key 21e and the key way 8p can be replaced by a key way corresponding to the key way 8p and a guide key corresponding to the guide key 21e, respectively.

【0099】

Although the guide key 21e is formed on the position-control cam bar 21a which includes the retracting cam surface 21c in the above illustrated embodiment, an element corresponding to the guide key 21e can be formed on any portion on the CCD holder 21 other than the position-control cam bar 21a. However, from a structural point of view, it is desirable that the guide

key 21e be formed together with the retracting cam surface 21c on the position-control cam bar 21a. In addition, to align the second lens group moving frame 8 and the position-control cam bar 21a precisely in the optical axis direction, it is desirable that the guide key 21e be formed on the position-control cam bar 21a which serves as an engaging portion which is engageable with the second lens frame 6 through the side second lens group moving frame 8.

【0100】

Not only the aforementioned reaction force that is exerted on the second lens group moving frame 8 while the retracting cam surface 21c presses the rear movable spring end 40b but also the positioning accuracy of each element of the retracting structure exert an adverse influence on the operating accuracy of the second lens frame 6. As described above, it is undesirable whether the range of rotation of the second lens frame 6 about the pivot shaft 33 from the photographing position to the radially retracted position is excessive or insufficient. However, if a force which may retract the second lens frame 6 beyond the radially retracted position shown in Figure 30 is applied to the second lens frame 6, a mechanical stress is applied to the retracting structure because cylindrical lens holder portion 6a and the stop arm portion 6e are brought very close to an inner peripheral surface of the second lens group moving frame

8 in the retracted state of the zoom lens 71 to achieve a space-saving retracting structure (see Figure 30). Accordingly, it is required to prevent such a mechanical stress from being applied to the retracting structure.

【0101】

To prevent such a mechanical stress from being applied to the retracting structure, not the position control arm 6j of the pivoted cylinder 6b but the rear movable spring end 40b of the rear torsion coil spring 40 serves as a portion which is to be engageable with the retracting cam surface 21c and the removed-position holding surface 21d when the second lens frame 6 retracts from the photographing position to the radially retracted position so that a slight error in movement of the second lens group 6 is absorbed by a resilient deformation of the rear torsion coil spring 40. Although the rear torsion coil spring 40 transfers a torque from the rear movable spring end 40b to the second lens group 6 via the front stationary spring end 40a without the front stationary spring end 40a and the rear movable spring end 40b being further pressed to move in opposite directions approaching each other than those shown in Figures 35 through 37 as mentioned above in a normal retracting operation of the zoom lens 71, the rear movable spring end 40b is further pressed to move in a direction approaching the front stationary spring end 40a than the rear movable spring end 40b shown in Figures

35 through 37 within the range $\theta 1$ (theta 1) shown in Figure 37 if the position-control cam bar 21a slightly deviates leftward as viewed in Figure 37 from the original position shown in Figure 37 since the rear movable spring end 40b is allowed to move in the first spring engaging hole 6k in the range $\theta 1$ (theta 1) as mentioned above. Accordingly, such a movement of the rear movable spring end 40b within the range $\theta 1$ (theta 1) can absorb the deviation of the position-control cam bar 21a from the original position thereof. To put it briefly, even if the position-control cam bar 21a further presses the rear movable spring end 40b in a state where the cylindrical lens holder portion 6a and the stop arm portion 6e are in contact with an inner peripheral surface of the second lens frame moving frame 8 (in a state where an outer peripheral portion of the cylindrical lens holder portion 6a and an outer edge of the stop arm portion 6e have entered the lens entering recess 8q and the stop arm portion entering recess 8r, respectively), an excessive mechanical stress is prevented from being applied to the retracting structure for the second lens frame 6 by a resilient deformation of the rear torsion coil spring 40.

【0102】

In the retracting structure for the second lens frame 6, when the second lens frame 6 is in the radially retracted position as shown in Figure 30, a radially

outside surface of the swing arm 6c is positioned to adjoin the bottom of the wide guide groove 8a-W to partly close the bottom of the wide guide groove 8a-W. In other words, the bottom of the wide guide groove 8a-W is formed on the radially outside of an intermediate point of a line extending between the axis of the pivot shaft 33 and the retracted optical axis Z2 of the second lens group LG2, and a part of the exposure control FPC board 77 is positioned on the radially outside of the intermediate point. Due to this structure, the swing arm 6c supports this part of the exposure control FPC board 77 from inside the second lens group moving frame 8 when the second lens frame 6 is positioned in the radially retracted position. Figure 43 shows the exposure control FPC board 77 and the second lens frame 6 by solid lines when the second lens frame 6 is positioned in the radially retracted position, and shows the second lens frame 6 by two-dot chain lines when the second lens frame 6 is positioned in the photographing position. It can be seen from Figure 43 that the swing arm 6c prevents the exposure control FPC board 77 from curving radially inwards by pushing the first straight portion 77a and the loop-shaped turning portion 77b of the exposure control FPC board 77 radially outwards

【0103】

Specifically, the swing arm 6c is provided with a straight flat surface 6q, and is further provided

immediately behind the straight flat surface 6q with an oblique support surface 6r. The swing arm 6c is further provided with an FPC-support projecting portion 6s which projects rearward from the oblique support surface 6r. In the retracted state of the second lens frame 6, the straight flat surface 6q is positioned to support the first straight portion 77a, while the oblique support surface 6r and the FPC-support projecting portion 6s are positioned to support the loop-shaped turning portion 77b.

【0104】

In an exposure control FPC board which extends between a movable element guided in an optical axis direction and a fixed element, the exposure control FPC board needs to be sufficiently long to cover the full range of movement of the movable element. Therefore, the exposure control FPC board tends to sag when the amount of advancement of the movable element is minimum, i.e., when the retractable lens is in the retracted state. Such a tendency of the exposure control FPC board is especially strong in the present embodiment of the zoom lens because the length of the zoom lens 71 is greatly reduced in the retracted state thereof by retracting the second lens group so that it is positioned on the retracted optical axis Z2 and also by adopting a three-stage telescoping structure for the zoom lens 71. Since interference of a sag of the exposure control FPC

board with internal elements of the retractable lens or jamming of a sag of the exposure control FPC board into internal elements of the retractable lens may cause a failure of the retractable lens, it is necessary for the retractable lens to be provided with a structure preventing such problems associated with the exposure control FPC board from occurring. However, this preventing structure is generally complicated in conventional retractable lenses. In the present embodiment of the zoom lens 71, in the view of the fact that the exposure control FPC board 77 tends to sag when the zoom lens 71 is in the retracted state, the loop-shaped turning portion 77b is pushed radially outwards by the second lens frame 6 positioned in the radially retracted position, which surely prevents the exposure control FPC board 77 from sagging with a simple structure.

【0105】

In the retracting structure for the second lens frame 6 in the present embodiment of the zoom lens, the moving path of the second lens frame 6 from the photographing position to the radially retracted position extends obliquely from a point (front point) on the photographing optical axis Z1 to a point (rear point) behind the front point above the photographing optical axis Z1 because the second lens frame 6 moves rearward in the optical axis direction while rotating about the

pivot shaft 33. On the other hand, the AF lens frame 51 is provided thereon between the front end surface 51c1 and the side surface 51c5 with a recessed oblique surface 51h. The recessed oblique surface 51h is inclined in a radially outward direction from the photographing optical axis Z1 from front to rear of the optical axis direction. In short, the edge of the forwardly-projecting lens holder portion 51c between the front end surface 51c1 and the side surface 51c5 is cut out along a moving path of the cylindrical lens holder portion 6a. Moreover, the front end surface 51c1 is formed as a concave surface which corresponds to the shape of an associated outer surface of the cylindrical lens holder portion 6a.

【0106】

As described above, the AF lens frame 51 moves rearward to the rear limit for the axial movement thereof (i.e., the retracted position), at which the AF lens frame 51 comes into contact with the stop surface 21b, before the commencement of retracting movement of the second lens frame 6 from the photographing position to the radially retracted position (see Figures 40 and 41). In this state in which the AF lens frame 51 is in contact with the stop surface 21b while the second lens frame 6 has not commenced to retract from the photographing position to the radially retracted position, if the second lens frame 6 starts moving rearward in the optical

axis direction while rotating about the pivot shaft 33 to retract to the radially retracted position, the rear end of the cylindrical lens holder portion 6a firstly moves obliquely rearward while approaching the recessed oblique surface 51h, and subsequently further moves obliquely rearward while grazing the recessed oblique surface 51h to finally reach a fully retracted position shown in Figure 41. Namely, the retracting operation for the second lens frame 6 from the photographing position to the radially retracted position can be performed at a closer point to the AF lens frame 51 in the optical axis direction by the amount of recess of the recessed oblique surface 51h.

【0107】

If the recessed oblique surface 51h or a similar surface is not formed on the AF lens frame 51, the retracting operation for the second lens frame 6 from the photographing position to the radially retracted position has to be completed at an earlier stage than that in the illustrated embodiment to prevent the cylindrical lens holder portion 6a from interfering with the AF lens frame 51. To this end, it is necessary to increase the amount of rearward movement of the second lens group moving frame 8 or the amount of projection of the position-control cam bar 21a from the CCD holder 22; this runs counter to downsizing of the zoom lens 71. If the amount of rearward movement of the second lens group

moving frame 8 is fixed, the inclination of the retracting cam surface 21c with respect to the photographing axis direction has to be increased. However, if this inclination is excessively large, the reaction force which is exerted on the position-control cam bar 21a and the second lens group moving frame 8 while the retracting cam surface 21c presses the rear movable spring end 40b is increased. Accordingly, it is undesirable that the inclination of the retracting cam surface 21c be increased to prevent a jerky motion from occurring in the retracting operation for the second lens frame 6. In contrast, in the present embodiment of the zoom lens, the retracting movement of the second lens frame 6 from the photographing position to the radially retracted position can be performed even after the AF lens frame 51 has retracted at a point very close to the AF lens frame 51 owing to the formation of the recessed oblique surface 51h. Therefore, even if the amount of rearward movement of the second lens group moving frame 8 is limited, the retracting cam surface 21c does not have to be shaped to be inclined largely with respect to the optical axis direction. This makes it possible reconcile a downsizing of the zoom lens 71 with a smoothing of the retracting movement of the second lens group moving frame 8. Similar to the AF lens frame 51, the CCD holder 21 is provided on a top surface thereof behind the recessed oblique surface 51h with a recessed

oblique surface 21f the shape of which is similar to the shape of the recessed oblique surface 51h. The recessed oblique surface 51h and the recessed oblique surface 21f are successively formed along a moving path of the cylindrical lens holder portion 6a to be shaped like a single oblique surface. Although the AF lens frame 51 serves as a movable member guided in the optical axis direction in the illustrated embodiment, a lens frame similar to the AF lens frame 51 can be provided with a recessed oblique surface corresponding to the recessed oblique surface 51h to incorporate features similar to the above described features of the recessed oblique surface 51h even if the lens frame similar to the AF lens frame 51 is of a type which is not guided in an optical axis direction.

【0108】

As can be understood from the above descriptions, the retracting structure for the second lens frame 6 is designed so that the second lens frame 6 does not interfere with the AF lens frame 51 when moving rearwards while retracting radially outwards to the radially retracted position in a state where the AF lens frame 51 has retracted to the rear limit (the retracted position) for the axial movement of the AF lens frame 51 as shown in Figures 40 and 41. In this state, upon the main switch being turned OFF, the control circuit 140 drives the AF motor 160 in the lens barrel retracting direction to move

the AF lens frame 51 rearward the retracted position thereof. However, if the AF lens frame 51 does not retract to the retracted position accidentally for some reasons upon the main switch being turned OFF, the AF lens frame 51 may interfere with the moving path of the second lens group 6 which is in the middle of moving rearward together with the second lens group moving frame 8 while rotating to the radially retracted position (see Figures 46 and 44).

【0109】

To prevent such a problem from occurring, the zoom lens 71 is provided with a fail-safe structure. Namely, the second lens frame 6 is provided on the swing arm 6c with the rear projecting portion 6m that projects rearward, beyond the rear end of the second lens group LG2, in the optical axis direction, while the AF lens frame 51 is provided, on that portion of the front end surface 51c1 of the forwardly-projecting lens holder portion 51c which faces the rear projecting portion 6m, with a rib-like forward protrusion 51f which projects forward from the front end surface 51c1 (see Figures 40, 41, and 44 through 47). As shown in Figure 47, the forward protrusion 51f is formed to lie in a plane orthogonal to the photographing optical axis Z1 to correspond to the range of rotation of the rear projecting portion 6m (the AF-frame contacting surface 6n) at the rotation of the second lens frame 6 from the

photographing position to the radially retracted position.

【0110】

With the fail-safe structure, even if the second lens frame 6 starts retracting to the radially retracted position in a state where the AF lens frame 51 does not retract to the retracted position and stops short of the retracted position, the AF-frame contacting surface 6n of the rear projecting portion 6m surely comes into contact with the rib-like forward protrusion 51f of the AF lens frame 51 first. This prevents the second lens group LG2 from coming into collision with the AF lens frame 51 to get scratched and damaged thereby even if such a malfunction occurs. In other words, since the moving path of the rear projecting portion 6m does not overlap the third lens group LG3 at any angular positions of the second lens frame 6 as shown in Figure 47, there is no possibility of any portions of the second lens group 6 other than the rear projecting portion 6m coming into contact with the third lens group LG3 to scratch the third lens group LG3. Accordingly, since the rear projecting portion 6m and the forward protrusion 51f are only the portions at which the second lens group LG6 and the AF lens frame 51 can contact with each other, the optical performances of the second lens group LG2 and the third lens group LG3 are prevented from deteriorating. If such a malfunction occurs, it is possible for the second

lens frame 6 in the process of moving rearward while rotating to the radially retracted position to push back, via the rear projecting portion 6m, the AF lens frame 51 forcefully which stops short of the retracted position.

【0111】

The AF-frame contacting surface 6n lies in a plane orthogonal to the photographing optical axis Z1, whereas the front surface of the forward protrusion 51f is formed as an inclined contacting surface 51g which is inclined to a plane orthogonal to the optical axis of the photographing optical axis Z1 by an angle of $\theta 2$ (theta 2) as shown in Figures 45 and 46. The inclined contacting surface 51g is inclined toward the rear of the optical axis direction in the direction of movement of the rear projecting portion 6m from a position when the second lens frame 6 is in the photographing position to a position when the second lens frame 6 is in the radially retracted position (upwards as viewed in Figures 45 through 47). Unlike the illustrated embodiment, if the front surface of the forward protrusion 51f is formed as a mere flat surface parallel to the AF-frame contacting surface 6n, the frictional resistance produced between the forward protrusion 51f and the AF-frame contacting surface 6n becomes great to impede a smooth movement of the second lens frame 6 in the event that the AF-frame contacting surface 6n comes into contact with the forward protrusion 51f when the second lens frame 6 is in the

process of moving rearward while rotating to the radially retracted position. In contrast, according to the present embodiment of the fail-safe structure, even if the AF-frame contacting surface 6n comes into contact with the forward protrusion 51f when the second lens frame 6 is in the middle of moving rearward while rotating to the radially retracted position, a great frictional resistance is not produced between the forward protrusion 51f and the AF-frame contacting surface 6n because of the inclination of the forward protrusion 51f with respect to the AF-frame contacting surface 6n. This makes it possible to retract the zoom lens 71 with reliability with less frictional force produced between the forward protrusion 51f and the AF-frame contacting surface 6n even if the aforementioned malfunction occurs. In the present embodiment of the fail-safe structure, the angle of inclination $\theta 2$ (theta 2) is set at three degrees as a desirable angle of inclination.

【0112】

It is possible that the forward protrusion 51f be formed so that the recessed oblique surface 51h can come into contact with the second lens group holding lid 9, that is fixed to the rear end of the cylindrical lens holder portion 6a, to serve as just like the inclined contacting surface 51g of the above illustrated embodiment of the fail-safe structure in the case where the AF lens frame 51 stops short of the retracted position

accidentally to a lesser extend that the rear projecting portion 6m comes into contact with the forward protrusion 51f.

【0113】

In the retracted position for the second lens frame 6, the position of the optical axis of the second lens group LG2 can be adjusted in directions lying in a plane orthogonal to the photographing optical axis Z1 in such a case where the optical axis of the second lens group LG2 is not coincident with the photographing optical axis Z1. Such an adjustment is carried out by two positioning devices: a first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8, and a second positioning device for adjusting the point of engagement of the eccentric pin 35b of the rotation limit shaft 35 with the stop arm portion 6e of the second lens frame 6. The positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 are adjusted by rotating the first eccentric shaft 34X and the second eccentric shaft 34Y. The point of engagement of the eccentric pin 35b with the stop arm portion 6e is adjusted by rotating the rotation limit shaft 35.

【0114】

First, the first positioning device for adjusting the positions of the front and rear second lens frame

support plates 36 and 37 relative to the second lens group moving frame 8 will be discussed hereinafter. As described above, the front eccentric pin 34X-b of the first eccentric shaft 34X is inserted into the first vertically-elongated hole 36a to be movable and immovable in the first vertically-elongated hole 36a in the lengthwise direction and the widthwise direction thereof, respectively, while the rear eccentric pin 34Y-b of the second eccentric shaft 34Y is inserted into the horizontally-elongated hole 36e to be movable and immovable in the horizontally-elongated hole 36e in the lengthwise direction and the widthwise direction thereof, respectively, as shown in Figures 28, 32 and 33. The lengthwise direction of the first vertically-elongated hole 36a, which corresponds to the vertical direction of the digital camera 70, is orthogonal to the lengthwise direction of the horizontally-elongated hole 36e, which corresponds to the horizontal direction of the digital camera 70. In the following descriptions, the lengthwise direction of the first vertically-elongated hole 36a is referred to as "Y-direction" while the lengthwise direction of the horizontally-elongated hole 36e is referred to as "X-direction".

【0115】

The lengthwise direction of the first vertically-elongated hole 37a is parallel to the

lengthwise direction of the first vertically-elongated hole 36a. Namely, the first vertically-elongated hole 37a is elongated in Y-direction. The first vertically-elongated hole 36a and the first vertically-elongated hole 37a are formed at opposed positions on the front and rear second lens frame support plates 36 and 37. The lengthwise direction of the horizontally-elongated hole 37e is parallel to the lengthwise direction of the horizontally-elongated hole 36e. Namely, the horizontally-elongated hole 37e is elongated in X-direction. The horizontally-elongated hole 36e and the horizontally-elongated hole 37e are formed at opposed positions on the front and rear second lens frame support plates 36 and 37. Similar to the front eccentric pin 34X-b, the rear eccentric pin 34X-c is movable and immovable in the first vertically-elongated hole 37a in Y-direction and X-direction, respectively, as shown in Figure 29. The front eccentric pin 34Y-b is movable and immovable in the horizontally-elongated hole 37e in X-direction and Y-direction, respectively.

【0116】

Similar to the pair of first vertically-elongated holes 36a and 37a and the pair of horizontally-elongated holes 36e and 37e, the lengthwise direction of the second vertically-elongated hole 36f is parallel to the lengthwise direction of the second vertically-elongated

hole 37f, while the second vertically-elongated hole 36f and the second vertically-elongated hole 37f are formed at opposed positions on the front and rear second lens frame support plates 36 and 37. The pair of the second vertically-elongated holes 36f and 37f are each elongated in Y-direction to extend parallel to the pair of first vertically-elongated holes 36a and 37a. The front boss 8j, which is engaged in the second vertically-elongated hole 36f, is movable and immovable in the second vertically-elongated hole 36f in Y-direction and X-direction, respectively. Similar to the front boss 8j, the rear boss 8k, which is engaged in the second vertically-elongated hole 37f, is movable and immovable in the second vertically-elongated hole 37f in Y-direction and X-direction, respectively.

【0117】

As shown in Figure 31, the large diameter portion 34X-a is inserted into the first eccentric shaft support hole 8f so as not to move in radial directions thereof, and is accordingly rotatable about the axis (adjustment axis PX) of the large diameter portion 34X-a. Likewise, the large diameter portion 34Y-a is inserted into the second eccentric shaft support hole 8i so as not to move in radial directions thereof, and is accordingly rotatable on the axis (adjustment axis PY1) of the large diameter portion 34Y-a. The front eccentric pin 34X-b and the rear eccentric pin 34X-c project eccentrically

with respect to the adjustment axis PX in Y-direction. The front eccentric pin 34X-b and the rear eccentric pin 34X-c have the same diameter and the common axis as mentioned above. The front eccentric pin 34Y-b and the rear eccentric pin 34Y-c project eccentrically with respect to the adjustment axis PY1 in X-direction (see Figure 33, and the front eccentric pin 34Y-b and the rear eccentric pin 34Y-c have the same diameter and the common axis.

【0118】

Therefore, a rotation of the second eccentric shaft 34Y on the adjustment axis PY1 causes the front and rear eccentric pins 34Y-b and 34Y-c to revolve about the adjustment axis PY1, i.e., rotate along a circle about the adjustment axis PY1, thus causing the front eccentric pin 34Y-b to push the front second lens frame support plate 36 in Y-direction while moving in X-direction and at the same time causing the rear eccentric pin 34Y-c to push the rear second lens frame support plate 37 in Y-direction while moving in X-direction. At this time, the front second lens frame support plate 36 moves linearly in Y-direction while guided in the same direction by the front eccentric pin 34Y-b and the front boss 8j since both the first vertically-elongated hole 36a and the second vertically-elongated hole 36f are elongated in Y-direction, and at the same time the rear second lens frame support plate 37 moves linearly in

Y-direction while guided in the same direction by the rear eccentric pin 34Y-c and the rear boss 8k since both the first vertically-elongated hole 37a and the second vertically-elongated hole 37f are elongated in Y-direction. Consequently, the position of the second lens frame 6 relative to the second lens group moving frame 8 varies to adjust the position of the optical axis of the second lens group LG2 in Y-direction.

【0119】

Therefore, a rotation of the first eccentric shaft 34X on the adjustment axis PX causes the front and rear eccentric pins 34X-b and 34X-c to revolve about the adjustment axis PX, i.e., rotate along a circle about the adjustment axis PX, thus causing the front eccentric pin 34X-b to push the front second lens frame support plate 36 in X-direction while moving in Y-direction and at the same time causing the rear eccentric pin 34X-c to push the rear second lens frame support plate 37 in X-direction while moving in Y-direction. At this time, although the front eccentric pin 34Y-b and the rear eccentric pin 34Y-c are respectively movable in the horizontally-elongated hole 36e and the horizontally-elongated hole 37e in X-direction, the front second lens frame support plate 36 swings about a fluctuant axis extending substantially parallel to the common axis of the front and rear bosses 8j and 8k in the vicinity of this common axis since the second

vertically-elongated hole 36f is immovable in X-direction relative to the front boss 8j and at the same time the rear second lens frame support plate 37 swings about the aforementioned fluctuant axis since the second vertically-elongated hole 37f is immovable in X-direction relative to the rear boss 8k. The position of the fluctuant axis corresponds to the following two resultant positions: a front resultant position between the position of the horizontally-elongated hole 36e relative to the front eccentric pin 34Y-b and the position of the second vertically-elongated hole 36f relative to the front boss 8j, and a rear resultant position between the position of the horizontally-elongated hole 37e relative to the rear eccentric pin 34Y-b and the position of the second vertically-elongated hole 37f relative to the rear boss 8k. Therefore, the fluctuant axis fluctuates in parallel to itself by a swing of the front and rear second lens frame support plates 36 and 37 about the aforementioned fluctuant axis. A swing of the front and rear second lens frame support plates 36 and 37 about the aforementioned fluctuant axis causes the pivot shaft 33 to move substantially linearly in X-direction. Therefore, the second lens group LG2 moves in X-direction by a rotation of the first eccentric shaft 34X on the adjustment axis PX.

【0120】

Figure 50 shows another embodiment of the first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8. This embodiment of the first positioning device is different from the above described first positioning device in that a front obliquely-elongated hole 36f′ and a rear obliquely-elongated hole 37f′ in which the front boss 8j and the rear boss 8k are engaged are formed on the front and rear second lens frame support plates 36 and 37 instead of the second vertically-elongated hole 36f and the second vertically-elongated hole 37f, respectively. The front obliquely-elongated hole 36f′ and the rear obliquely-elongated hole 37f′ extend parallel to each other obliquely to both X-direction and Y-direction, and are aligned in the optical axis direction. Since each of the front obliquely-elongated hole 36f′ and the rear obliquely-elongated hole 37f′ includes both a component in X-direction and a component in Y-direction, a rotation of the second eccentric shaft 34Y on the adjustment axis PY1 causes the front obliquely-elongated hole 36f′ and the rear obliquely-elongated hole 37f′ to move in Y-direction while moving in X-direction slightly relative to the front boss 8j and the rear boss 8k, respectively. Consequently, the front and rear second lens frame support plates 36 and 37 move in Y-direction while the

respective lower end portions thereof swing slightly in X-direction. On the other hand, a rotation of the first eccentric shaft 34X on the adjustment axis PX causes the front and rear second lens frame support plates 36 and 37 to move in X-direction while moving (swinging) slightly in Y-direction. Accordingly, the position of the second lens group LG2 can be adjusted in directions lying in a plane orthogonal to the photographing optical axis Z1 by a combination of an operation of the first eccentric shaft 34X and an operation of the second eccentric shaft 34Y.

【0121】

The set screw 66 needs to be loosened before the position of the optical axis of the second lens group LG2 is adjusted by operating the first eccentric shaft 34X and the second eccentric shaft 34Y. The set screw 66 is tightened after the adjustment operation is completed. Thereafter, the front and rear second lens frame support plates 36 and 37 are tightly fixed to the front fixing surface 8c and the rear fixing surface 8e to be held at their respective adjusted positions. Therefore, the pivot shaft 33 is also held at its adjusted position. Consequently, the position of the optical axis of the second lens group LG2 is held at its adjusted position since the position of the optical axis of the second lens group LG2 depends on the position of the pivot shaft 33. As a result of the optical axis position adjustment

operation, the set screw 66 has been moved from the previous position thereof; however, this presents no problem. This is because the set screw 66 does not move to such an extent as to interfere with the second lens group moving frame 8 by the optical axis position adjustment operation since the threaded shaft portion 66a is loosely fitted in the screw insertion hole 8h as shown in Figure 31.

【0122】

A two-dimensional positioning device which incorporates a first movable stage movable linearly along a first direction and a second movable stage movable linearly along a second direction perpendicular to the first direction, wherein an object the position of which is to be adjusted is mounted on the second movable stage, is known in the art. The structure of this conventional two-dimensional positioning device is generally complicated. In contrast, the above illustrated first positioning device for adjusting the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 is simple because each of the front second lens frame support plate 36 and the rear second lens frame support plate 37 is supported to be movable thereon in both X-direction and Y-direction, which makes it possible to achieve a simple two-dimensional positioning device. Although the above illustrated first positioning

device includes two support plates (the pair of second lens frame support plates 36 and 37) for supporting the second lens frame 6, which are positioned separately from each other in the optical axis direction, to increase a stability of the structure supporting the second lens frame 6, it is possible that the second lens frame 6 be supported with only one of the two support plates. In this case, the first positioning device has only to be provided on the one support plate.

【0123】

In the above illustrated embodiment of the first positioning device, since the front second lens frame support plate 36 and the rear second lens frame support plate 37 are arranged on front and rear sides of the second lens group moving frame 8, each of the first and second eccentric shafts 34X is provided at the front and rear ends thereof with a pair of eccentric pins (34X-b and 34X-c), respectively, and the second lens group moving frame 8 is provided on front and rear sides thereof with a pair of bosses (8j and 8k), respectively, the pair of second lens frame support plates 36 and 37 move while remaining parallel to each other when either eccentric shafts 34X or 34Y rotates together by the same amount of rotation in the same rotational direction. For instance, even if either one of the front eccentric pin 34X-b or the rear eccentric pin 34X-c is manually rotated, the front second lens frame support plate 36 and the rear second lens frame support plate 37 move equally in the X-direction by the same amount of movement.

Likewise, even if either one of the front eccentric pin 34Y-b or the rear eccentric pin 34Y-c is manually rotated, the front second lens frame support plate 36 and the rear second lens frame support plate 37 move equally in the Y-direction by the same amount of movement. Although it will be discussed below that the first and second eccentric shafts 34X and 34Y are each rotated with a screwdriver engaged in the recesses 34X-d and 34Y-d, respectively, during this operation the rear second lens frame support plate 37 properly follows the movement of the front second lens frame support plate 36 without being warped. Accordingly, the optical axis of the second lens group LG2 does not tilt by an operation of the first positioning device, which makes it possible to adjust the position of the optical axis of the second lens group LG2 two-dimensionally in directions lying in a plane orthogonal to the photographing optical axis Z1 with a high degree of precision.

【0124】

Since the first and second eccentric shafts 34X and 34Y are supported and held between the first and second eccentric shafts 34X and 34Y disposed on front and rear sides of the shutter unit 76, each of the first and second eccentric shafts 34X and 34Y is elongated so that the length thereof becomes close to the length of the second lens group moving frame 8 in the optical axis direction, just as the length of the pivot shaft 33. This prevents the second lens group moving frame 8 from tilting, which accordingly makes it possible to adjust the position of the optical axis of the second lens group LG2

two-dimensionally in directions lying in a plane orthogonal to the photographing optical axis Z1 with a higher degree of precision.

【0125】

Subsequently, the second positioning device for adjusting the point of engagement of the eccentric pin 35b of the rotation limit shaft 35 with the stop arm portion 6e of the second lens frame 6 will be hereinafter discussed. As shown in Figures 29 and 30, the large diameter portion 35a of the rotation limit shaft 35 is rotatably fitted in the rotation limit shaft insertion hole 8m with the eccentric pin 35b projecting rearward from the rear end of the rotation limit shaft insertion hole 8m. Note that the large diameter portion 35a of the rotation limit shaft 35 does not rotate by itself with respect to the rotation limit shaft insertion hole 8m, however, if a predetermined amount of force is applied, it is possible for the large diameter portion 35a to be rotated. As shown in Figure 27, the eccentric pin 35b is positioned at moving path of the tip of the stop arm portion 6e of the second lens frame 6. The eccentric pin 35b projects rearward from the rear end of the large diameter portion 35a so that the axis of the eccentric pin 35b is eccentric from the axis of the large diameter portion 35a as shown in Figure 34. Therefore, a rotation of the eccentric pin 35b on an axis thereof (adjustment axis PY2) causes the eccentric pin 35b to revolve about

the adjustment axis PY2, thus causing the eccentric pin 35b to move in the Y-direction. Since the eccentric pin 35b of the rotation limit shaft 35 serves as an element for determining the photographing position of the second lens frame 6, a displacement of the eccentric pin 35b in the Y-direction causes the second lens group LG2 to move in the Y-direction. Therefore, the position of the optical axis of the second lens group LG2 can be adjusted in the Y-direction by an operation of the rotation limit shaft 35. Accordingly, the position of the optical axis of the second lens group LG2 can be adjusted in the Y-direction by the combined use of the rotation limit shaft 35 and the second eccentric shaft 34Y. It is desirable that the rotation limit shaft 35 be operated secondarily in a particular case where the range of adjustment of the second eccentric shaft 34Y is insufficient.

【0126】

As shown in Figure 28, the screwdriver engaging recess 34X-d of the first eccentric shaft 34X, the recess 34Y-d of the second eccentric shaft 34Y and the screwdriver engaging recess 35c of the rotation limit shaft 35 are all exposed to the front of the second lens group moving frame 8. In addition, the head of the set screw 66 that is provided with the screwdriver engaging recess 66b is exposed to the front of the second lens group moving frame 8. Due to this structure, the

position of the optical axis of the second lens group LG2 can be adjusted two-dimensionally with the above described first and second positioning devices from the front of the second lens group moving frame 8, i.e., all the operating members of the first and second positioning devices are accessible from the front of the second lens group moving frame 8. On the other hand, the first external barrel 12, that is positioned radially outside the second lens group moving frame 8, is provided on an inner peripheral surface thereof with the inner flange 12c which projects radially inwards to close the front of the second lens group moving frame 8 in cooperation with the fixing ring 3.

【0127】

As shown in Figures 48 and 49, the first external barrel 12 is provide on the inner flange 12c with four screwdriver insertion holes 12d, 12e, 12f and 12g each having a circular cross section. The screwdriver insertion holes 12d, 12e, 12f and 12g penetrate the inner flange 12c in the optical axis direction so that the screwdriver engaging recess 34X-d, the recess 34Y-d, the screwdriver engaging recess 35c and the screwdriver engaging recess 66b are exposed to the front of the first external barrel 12, respectively. Portions of the fixing ring 3 which are aligned with the four screwdriver insertion holes 12d, 12e, 12f and 12g are also cut out to have circular cross sections, respectively. With the four screwdriver insertion holes 12d, 12e, 12f and 12g of the first external barrel 12, a screwdriver can be

brought into engagement with the screwdriver engaging recess 34X-d, the recess 34Y-d, the screwdriver engaging recess 35c and the screwdriver engaging recess 66b from the front of the second lens group moving frame 8 through the four screwdriver insertion holes 12d, 12e, 12f and 12g, respectively, without removing the first external barrel 12 from the front of the second lens group moving frame 8. The respective front ends of the four screwdriver insertion holes 12d, 12e, 12f and 12g are exposed to the front of the zoom lens 71 by removing the lens barrier cover 101 and the aforementioned lens barrier mechanism positioned immediately behind the lens barrier cover 101. Due to this structure, the position of the optical axis of the second lens group LG2 can be adjusted two-dimensionally with the above described first and second positioning devices from the front of the second lens group moving frame 8 without dismounting fundamental components of the zoom lens 71 except for substantially the lens barrier mechanism, i.e., in substantially finished form. Accordingly, the position of the optical axis of the second lens group LG2 two-dimensionally can be easily adjusted with the first and second positioning devices in a final assembling process even if a deviation of the second lens group LG2 the degree of which is out of tolerance occurs in assembly work. This results in an improvement in workability of the assembly work.

【0128】

[DESCRIPTION OF A FEATURE OF PRESENT INVENTION]

As has been described, when the zoom lens 71 changes from the ready-to-photograph state to the retracted state, the cylindrical lens holder portion 6a of the second lens frame 6, which holds the second lens group LG2, rotates about the pivot pin 33 in a direction away from the photographing optical axis Z1 in the inside of the second lens group moving frame 8, while the AF lens frame 51 that holds the third lens group LG3 enters that space in the second lens group moving frame 8 from which the lens holder portion 6a has retracted (see Figures 52, 54 and 56). In addition, when the zoom lens 71 changes from the ready-to-photograph state to the retracted state, the first lens frame 1 that holds the first lens group LG1 enters the second lens group moving frame 8 from the front thereof (see Figures 51 and 53). Accordingly, the second lens group moving frame 8 has to be provided with two internal spaces: a front internal space immediately in front of the central inner flange 8s in which the first lens frame 1 is allowed to move in the optical axis direction, and a rear internal space immediately behind the central inner flange 8s in which the second lens frame 6 is allowed to retract in a radial direction of the second lens frame 6 and in which the AF lens frame 51 is allowed to move in the optical axis direction. In the present embodiment of the zoom lens, the shutter unit 76, specifically an actuator thereof, is disposed inside the second lens group moving frame 8,

which accommodates more than one lens group therein, in a space-saving manner to maximize the internal space of the second lens group moving frame 8.

【0129】

Figure 58 shows the fundamental elements of the shutter unit 76. The shutter unit 76 is provided with a base plate 120 having a central circular aperture 120a with its center on the photographing optical axis Z1. The base plate 120 is provided on a front surface thereof (a surface which can be seen in Figure 58) above the circular aperture 120a with a shutter-actuator support portion 120b formed integral with the base plate 120. The shutter-actuator support portion 120b is provided with an accommodation recess 120b1 in which the shutter actuator 131 is accommodated. After the shutter actuator 131 is embedded in the accommodation recess 120b1, a holding plate 121 is fixed to the shutter-actuator support portion 120b so that the shutter actuator 131 is supported by the base plate 120 on the front thereof. The shutter unit 76 is provided with a diaphragm-actuator support member 120c which is fixed to the back of the base plate 120 on the right side of the cylindrical recess 120b1 as viewed from the rear of the base plate 120. The shutter unit 76 is provided with a diaphragm-actuator support cover 122 having an accommodation recess 122a in which the diaphragm actuator 132 is accommodated. The diaphragm-actuator

support cover 122 is fixed to the diaphragm-actuator support member 120c. After the diaphragm actuator 132 is embedded in the accommodation recess 122a, the diaphragm-actuator support cover 122 is fixed to the back of the diaphragm-actuator support member 120c so that the diaphragm actuator 132 is supported by the diaphragm-actuator support member 120c on the back thereof. The shutter unit 76 is provided with a cover ring 123 which is fixed to the diaphragm-actuator support cover 122 to cover an outer peripheral surface thereof. The holding plate 121 is fixed to the shutter-actuator support portion 120b by a set screw 129a. The diaphragm-actuator support member 120c is fixed to the back of the base plate 120 by two set screws 129b and 129c. A lower end portion of the diaphragm-actuator support member 120c which is provided with a screw hole into which the set screw 129b is screwed is formed as a rearward-projecting portion 120c1.

【0130】

The shutter S and the adjustable diaphragm A are mounted to the rear of the base plate 120 immediately beside the diaphragm-actuator support member 120c. The shutter S is provided with a pair of shutter blades S1 and S2, and the adjustable diaphragm A is provided with a pair of diaphragm blades A1 and A2. The pair of shutter blades S1 and S2 are pivoted on a first pair of pins projecting rearward from the back of the base plate 120,

respectively, and the pair of diaphragm blades A1 and A2 are pivoted on a second pair of pins projecting rearward from the back of the base plate 120, respectively. The shutter unit 76 is provided between the shutter S and the adjustable diaphragm A with a partition plate 125 which prevents the shutter S and the adjustable diaphragm A from interfering with each other. A blade-holding plate 126 is fixed to the back of the base plate 120 to hold the shutter S, the partition plate 125 and the adjustable diaphragm A between the base plate 120 and the blade-holding plate 126. The partition plate 125 and the blade-holding plate 126 are provided with a circular aperture 125a and a circular aperture 126a, respectively, through which rays of light of an object image which is to be photographed pass. The circular apertures 125a and 126a are aligned with the central circular aperture 120a of the base plate 120.

【0131】

The shutter actuator 131 is provided with a rotor, a rotor magnet (permanent magnet), a stator made of steel, and a bobbin. The rotor is provided with a drive arm 131a which projects rearwards from the tip of the radial arm portion to be inserted into cam grooves S1a and S2a of the pair of shutter blades S1 and S2. Strands (not shown) through which electric current is passed via the flexible PWB 77 to control rotation of the rotor are wound on the bobbin. Passing a current through the

strands wound on the bobbin causes the rotor to rotate forward or reverse depending on the magnetic field which varies in accordance with the direction of the passage of the current. Rotations of the rotor forward and reverse cause the drive arm 131a to swing in forward and revere directions, thus causing the pair of shutter blades S1 and S2 to open and close, respectively, by engagement of the drive arm 131a with the cam grooves S1a and S2a.

The diaphragm actuator 132 is provided with a rotor and a rotor magnet (permanent magnet). The rotor is provided with a drive arm 132a which projects rearwards from the tip of the radial arm portion to be inserted into cam grooves A1a and A2a of the pair of diaphragm blades A1 and A2. Strands (not shown) through which electric current is passed via the flexible PWB 77 to control rotation of the rotor are wound on the diaphragm-actuator support member 120c and the diaphragm-actuator support cover 122. Passing a current through the strands wound on the diaphragm-actuator support member 120c and the diaphragm-actuator support cover 122 causes the rotor to rotate forward or reverse depending on the magnetic field which varies in accordance with the direction of the passage of the current. Rotations of the rotor forward and reverse cause the drive arm 132a to swing in forward and revere directions, thus causing the pair of diaphragm blades A1 and A2 to open and close, respectively, by

engagement of the drive arm 132a with the cam grooves A1a and A2a.

【0132】

The shutter unit 76 is prepared as a subassembly in advance, and fitted into the second lens group moving frame 8 to be fixed thereto. As shown in Figures 26 and 28, the shutter unit 76 is supported by the second lens group moving frame 8 therein so that the base plate 120 is positioned immediately in front of the central inner flange 8s. A terminal end 77e of the flexible PWB 77 is fixed to a front surface of the holding plate 121 (see Figures 26 51 and 53).

【0133】

The second lens group moving frame 8 has a cylindrical shape coaxial to other rotatable rings such as the cam ring 11. The axis of the second lens group moving frame 8 coincides with the lens barrel axis Z0 of the zoom lens 71. The photographing optical axis Z1 is eccentric downward from the lens barrel axis Z0 to secure some space in the second lens group moving frame 8 into which the second lens group LG2 is retracted (see Figures 28 through 30). On the other hand, the first lens frame 1, which supports the first lens group LG1, is in the shape of a cylinder with its center on the photographing optical axis Z1, and is guided along the photographing optical axis Z1. Due to this structure, the space in the second lens group moving frame 8 which is occupied by the

first lens group LG1 is secured in the second lens group moving frame 8 below the lens barrel axis Z0. Accordingly, sufficient space (upper front space) is easily secured in the second lens group moving frame 8 in front of the central inner flange 8s on the opposite side of the lens barrel axis Z0 from the photographing optical axis Z1 (i.e., above the lens barrel axis Z0) so that the shutter actuator 131 and supporting members therefor (the shutter-actuator support portion 120b and the holding plate 121) are positioned in the upper front space along an inner peripheral surface of the second lens group moving frame 8. With this structure, the first lens frame 1 does not interfere with either the shutter actuator 131 or the holding plate 121 even if the first lens frame 1 enters the second lens group moving frame 8 from the front thereof as shown in Figure 53. Specifically, in the retracted state of the zoom lens 71, the holding plate 121 and the shutter actuator 131, which is positioned behind the holding plate 121, are positioned in an axial range in which the first lens group LG1 is positioned in the optical axis direction; namely, the holding plate 121 and the shutter actuator 131 are positioned radially outside the first lens group LG1. This maximizes the utilization of the internal space of the second lens group moving frame 8, thus contributing to a further reduction of the length of the zoom lens 71.

【0134】

The first lens frame 1 that holds the first lens group LG1 is positioned in the first external barrel 12 to be supported thereby via the first lens group adjustment ring 2 as shown in Figure 56 to be movable together with the first external barrel 12 in the optical axis direction though the first lens group adjustment ring 2 is not shown in Figures 51 and 53 around the first lens frame 1 for the purpose of illustration. The inner flange 12c of the first external barrel 12 is provided, above the portion thereof which holds the first lens frame 1 and the first lens group adjustment ring 2, with a through hole 12c1 which has a substantially arm shape and which penetrates the first external barrel 12 in the optical axis direction (see Figures 48 and 49). The through hole 12c1 is shaped so that the holding plate 121 can enter the through hole 12c1 from behind. The holding plate 121 enters the through hole 12c1 as shown in Figure 56 when the zoom lens 71 is in the retracted position.

【0135】

In the rear internal space of the second lens group moving frame 8 behind the central inner flange 8s, not only the forwardly-projecting lens holder portion 51c (the third lens group LG3) of the AF lens frame 51 moves in and out in the optical axis direction above the photographing optical axis Z1 that is positioned below the lens barrel axis Z0 but also the cylindrical lens holder portion 6a retracts into the space on the opposite

side of the lens barrel axis Z0 from the photographing optical axis Z1 when the zoom lens 71 is retracted into the camera body 72; accordingly, there is substantially no extra space in the second lens group moving frame 8 behind the central inner flange 8s in a direction (vertical direction) of a straight line M1 orthogonally intersecting both the lens barrel axis Z0 and the photographing optical axis Z1 (see Figures 30 and 55). Whereas, substantial two side spaces not interfering with either the second lens group LG2 or the third lens group LG3 are successfully secured on respective sides (right and left sides) of the line M1 in the second lens group moving frame 8 along an inner peripheral surface thereof behind the central inner flange 8s in a direction of a straight line M2 which orthogonal to the straight line M2 and intersects the photographing optical axis Z1. As can be seen in Figures 29 and 30, the left side space of the two side spaces which is positioned on the left side of the lens barrel axis Z0 and the photographing optical axis Z1 as viewed from the rear of the second lens frame 8 is utilized partly as the space for the swing arm portion 6c of the swingable second lens frame 6 to swing therein and partly as the space for accommodating the above described first positioning device, with which the positions of the front and rear second lens frame support plates 36 and 37 relative to the second lens group moving frame 8 can be adjusted. The right side space of the

aforementioned two side spaces which is positioned on the right side is utilized as the space for accommodating the diaphragm actuator 132 and supporting members therefor (the diaphragm-actuator support cover 122 and the cover ring 123) so that the diaphragm actuator 132 and the supporting members are positioned along an inner peripheral surface of the second lens group moving frame 8. More specifically, the diaphragm actuator 132 and the supporting members (the diaphragm-actuator support cover 122 and the cover ring 123) lie on the aforementioned straight line M2. Accordingly, as can be understood from Figures 29, 30 and 55, the diaphragm actuator 132, the diaphragm-actuator support cover 122 and the cover ring 123 do not interfere with either the range of movement of the second lens group LG2 or the range of movement of the third lens group LG3.

【0136】

Specifically, in the inside of the second lens group moving frame 8 behind the central inner flange 8s, the second lens group LG2 (the cylindrical lens holder portion 6a) and the third lens group LG3 (forwardly-projecting lens holder portion 51c) are accommodated on upper and lower sides of the lens barrel axis Z0, respectively, while the above described first positioning device and diaphragm actuator 132 are positioned on right and left sides of the lens barrel axis Z0 when the zoom lens 71 is in the retracted state. This

maximizes the utilization of the internal space of the second lens group moving frame 8 in the retracted state of the zoom lens 71. In this state, the diaphragm-actuator support cover 122, the cover ring 123 and the diaphragm actuator 132 are positioned in the space radially outside the space in which the second lens group LG2 and the third lens group LG3 are accommodated. This contributes to a further reduction of the length of the zoom lens 71.

【0137】

In the present embodiment of the zoom lens, the base plate 120 of the shutter unit 120 is positioned in front of the central inner flange 8s, whereas the diaphragm actuator 132, the diaphragm-actuator support cover 122 and the cover ring 123 are positioned behind the central inner flange 8s. In order to make respective front portions of the diaphragm actuator 132, the diaphragm-actuator support cover 122 and the cover ring 123 positioned in front of the front of the central inner flange 8s, the central inner flange 8s is provided with a through hole 8s1 in which the cover ring 123 is fitted. The central inner flange 8s is further provided below the through hole 8s1 with an accommodation recess 8s2 in which the rearward-projecting portion 120c1 of the diaphragm-actuator support member 120c is accommodated.

【0138】

The forwardly-projecting lens holder portion 51c of

the AF lens frame 51 is provided, on the side surface 51c4 among the four side surfaces 51c3, 51c4, 51c5 and 51c6 around the forwardly-projecting lens holder portion 51c, with a recess 51i which is formed by cutting out a part of the forwardly-projecting lens holder portion 51c. The recess 51i is formed to correspond to the shapes of outer peripheral surfaces of the ring cover 123 and the accommodation recess 8s2 of the second lens group moving frame 8 so that the forwardly-projecting lens holder portion 51c does not interfere with the ring cover 123 and the accommodation recess 8s2 in the retracted state of the zoom lens 71. Namely, the outer peripheral portions of the ring cover 123 and the accommodation recess 8s2 partly enter the recess 51i when the zoom lens 71 is fully retracted into the camera body 72 (see Figures 39, 47 and 55). This further maximizes the utilization of the internal space of the second lens group moving frame 8 to minimize the length of the zoom lens 71.

【0139】

As can be understood from the above descriptions, although the shutter actuator 131 and the diaphragm actuator 132 are structured in consideration of the utilization of the internal space of the zoom lens 71 in the present embodiment of the zoom lens 71, the present invention is not limited solely to the particular embodiment of the zoom lens described above and the technical idea thereof. For instance, although the

above illustrated embodiment of the lens barrel is a zoom lens barrel, the present invention can also be applied to a fixed-focal-length lens barrel as long as the length thereof can be reduced when the lens barrel changes from a ready-to-photograph state to a retracted state. In addition, although applied to the lens barrel of a digital camera in the above illustrated embodiment, the present invention can be applied to any other optical devices.

【0140】

【Effects of the Invention】

As can be understood from the foregoing, according to the present invention, actuators for actuating exposure control components can be disposed in a space-saving manner in a lens barrel which is capable of retracting an optical element of a photographing optical system to a position deviating from the photographing optical axis of the photographing optical system.

【BRIEF DESCRIPTION OF THE DRAWING】

Figure 1 is an exploded perspective view of an embodiment of a zoom lens according to the present invention;

Figure 2 is an exploded perspective view of a structure supporting a first lens group of the zoom lens;

Figure 3 is an exploded perspective view of a structure supporting a second lens group of the zoom lens;

Figure 4 is an exploded perspective view of a barrel-advancing structure from a stationary barrel to a cam ring;

Figure 5 is a perspective view of the zoom lens shown in Figure 1, showing a completed state thereof to which a zoom motor and a viewfinder unit are fixed;

Figure 6 is a longitudinal cross sectional view of a camera incorporating the zoom lens shown in Figure 1, showing a state of the zoom lens at telephoto extremity and a state of the zoom lens at wide-angle extremity;

Figure 7 is a longitudinal cross sectional view of the camera shown in Figure 6 in the retracted state of the zoom lens;

Figure 8 is a plan view of the stationary barrel;

Figure 9 is a plan view of a helicoid ring;

Figure 10 is a plan view of the helicoid ring, showing a structure of the inner peripheral surface thereof by broken lines;

Figure 11 is a plan view of a third external barrel;

Figure 12 is a plan view of a linear guide ring;

Figure 13 is a plan view of the cam ring;

Figure 14 is a plan view of the cam ring, showing a structure of the inner peripheral surface thereof by broken lines;

Figure 15 is a plan view of a second linear guide ring;

Figure 16 is a plan view of a second lens group

moving frame;

Figure 17 is a plan view of a second external barrel;

Figure 18 is a plan view of a first external barrel;

Figure 19 is a conceptual diagram of elements of the zoom lens, showing the relationship among these elements;

Figure 20 is an exploded perspective view of a structure of the zoom lens for supporting a second lens frame which holds the second lens group;

Figure 21 is a perspective view of the structure for the second lens frame shown in Figure 20 in an assembled state, viewed obliquely from the front;

Figure 22 is a rear perspective view of the structure shown in Figure 21, viewed obliquely from behind;

Figure 23 is a view similar to that of Figure 22, showing a state where a position-control cam bar is in the process of entering the cam-bar insertable hole of a rear second lens frame support plate fixed to the second lens group moving frame;

Figure 24 is a front elevational view of the second lens group moving frame;

Figure 25 is a perspective view of the second lens group moving frame;

Figure 26 is a perspective view of the second lens group moving frame and the shutter unit fixed thereto, viewed obliquely from front;

Figure 27 is a perspective view of the second lens group moving frame and the shutter unit shown in Figure 26, viewed obliquely from behind;

Figure 28 is a front elevational view of the second lens group moving frame and the shutter unit shown in Figure 26;

Figure 29 is a rear elevational view of the second lens group moving frame and the shutter unit shown in Figure 26;

Figure 30 is a view similar to that of Figure 29, showing a state where the second lens frame has retracted to the radially retracted position;

Figure 31 is a cross sectional view taken along XXXI-XXXI line shown in Figure 28;

Figure 32 is a front elevational view of the structure for the second lens frame, showing a state where the second lens frame is held at a photographing position thereof as shown in Figure 28;

Figure 33 is a front elevational view of a fundamental portion of the structure for the second lens frame shown in Figure 32, which uses first and second eccentric shafts;

Figure 34 is a front elevational view of a fundamental portion of the structure for the second lens frame which includes a rotation limit shaft;

Figure 35 is a front elevational view of a fundamental portion of the structure for the second lens

frame, showing the positional relationship between the second lens frame and the position-control cam bar when the second lens frame is held in a photographing position thereof;

Figure 36 is a view similar to that of Figure 35, showing a positional relationship between the second lens frame and the position-control cam bar;

Figure 37 is a view similar to that of 35, showing the positional relationship between the second lens frame and the position-control cam bar when the second lens frame is held in the radially retracted position;

Figure 38 is a perspective view of an AF lens frame and the CCD holder, showing a state where the AF lens frame is retracted, viewed obliquely from lower front of the CCD holder;

Figure 39 is a front elevational view of the CCD holder, the AF lens frame and the second lens group moving frame;

Figure 40 is a perspective view of the AF lens frame and the CCD holder, showing a state where the AF lens frame is retracted to a point immediately before it contacts with and the CCD holder, viewed obliquely from lower front of the CCD holder;

Figure 41 is a view similar to that of Figure 40, showing a state where the second lens frame has fully moved rearward and fully rotated to the radially retracted position;

Figure 42 is an axial cross sectional view of a portion of the zoom lens, showing a structure wiring an exposure control FPC board in the zoom lens;

Figure 43 is a perspective view of the second lens frame, the exposure control FPC board and other elements, showing a manner of supporting the exposure control FPC board by the second lens frame;

Figure 44 is a perspective view of the second lens frame and the AF lens frame, showing a state where the second lens frame has retracted closely to the AF lens frame;

Figure 45 is a side elevational view of the second lens frame and the AF lens frame, showing a state immediately before the second lens frame comes into contact with the AF lens frame;

Figure 46 is a view similar to that of Figure 45, showing a state where the second lens frame is in contact with the AF lens frame;

Figure 47 is a front elevational view of the second lens frame and the AF lens frame, showing a positional relationship therebetween;

Figure 48 is a perspective view of the first external barrel that surrounds the second lens group moving frame;

Figure 49 is a front elevational view of the first external barrel and the first lens frame;

Figure 50 is a front elevational view of another

embodiment of the structure for the second lens frame that uses first and second eccentric shafts;

Figure 51 is a perspective view of the first lens frame, the second lens group moving frame (the second lens frame 6), the AF lens frame and the shutter unit, viewed obliquely from front, showing the positional relationship thereamong at a ready-to-photograph state of the zoom lens;

Figure 52 is a perspective view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 51, viewed obliquely from rear thereof;

Figure 53 is a view similar to that of Figure 133, showing the positional relationship among the first lens frame, the second lens group moving frame (the second lens frame 6), the AF lens frame and the shutter unit, showing the positional relationship thereamong in the retracted state of the zoom lens;

Figure 54 is a perspective view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 53, viewed obliquely from rear thereof;

Figure 55 is a rear elevational view of the first lens frame, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 53;

Figure 56 is a perspective view, of the first lens

frame, the first external barrel, the second lens group moving frame, the AF lens frame and the shutter unit in the retracted state of the zoom lens, showing the positional relationship thereamong in the retracted state of the zoom lens shown in Figure 53;

Figure 57 is a front elevational view of the first lens frame, the first external barrel, the second lens group moving frame, the AF lens frame and the shutter unit which are shown in Figure 56; and

Figure 58 is an exploded perspective view of the shutter unit of the zoom lens.

【DESCRIPTIONS OF THE NUMERALS】

LG1 first lens group (front lens group)

LG2 second lens group (intermediate lens group)

LG3 third lens group (rear lens group)

LG4 low-pass filter

S shutter (exposure control component)

S1 S2 shutter blades

A diaphragm (exposure control component)

A1 A2 diaphragm blades

Z0 lens barrel axis (axis of an annular body)

Z1 photographing optical axis (eccentric photographing optical axis)

Z2 optical axis of the second lens group

Z3 optical axis of an objective optical system of a viewfinder

PX PY1 PY2 adjustment axes

1 first lens frame

1a male screw thread for adjustment

1b contacting portion

2 first lens group adjustment ring

2a female screw thread

2b guide projections

2c engaging projections

3 fixing ring

3a spring receiving portions

6 second lens frame

6a cylindrical lens holder portion

6b pivoted cylinder

6c swing arm

6d pivot hole

6e stop arm portion

6f front spring support portion

6g rear spring support portion

6h 6i spring hold projections

6j position control arm

6k 6p spring engaging holes

6m rear projecting portion

6n AF-frame contacting surface

6q straight flat surface

6r oblique support surface

6s FPC-support projecting portion

8 second lens group moving frame (optical-element-accommodating ring member)

8a 8a-W linear guide groove

8b cam followers for the second lens group

8b-1 front cam followers

8b-2 rear cam followers

8c front fixing surface

8d partial cylinder portion

8e rear fixing surface

8f eccentric shaft support hole

8g pivoted cylinder receiving hole

8h screw insertion hole

8i eccentric shaft support hole

8j front boss

8k rear boss

8m rotation limit shaft insertion hole

8n through internal space

8p key way

8q lens entering recess

8r stop arm portion entering recess

8s central inner flange

8s1 through hole

8s2 accommodation recess

8t second lens group traveling opening

9 second lens group holding lid

10 second linear guide ring (linear guide ring)

10a bifurcated projections

10b ring portion

10c 10c-W linear guide keys

10d FPC-passing through hole

11 cam ring (rotatable ring)

11a cam grooves for guiding the second lens group

11a-1 front cam grooves

11a-2 rear cam grooves

11b cam grooves for guiding the first lens group

11c 11e circumferential grooves

11d barrier drive ring pressing surface

12 the first external barrel

12a engaging protrusions

12b first guide grooves for adjustment of the first lens group

12c inner flange

12c1 through hole

12d screwdriver insertion hole

12e screwdriver insertion hole

12f screwdriver insertion hole

12g screwdriver insertion hole

13 second external barrel

13a linear guide projections

13b linear guide grooves

13c inner flange

14 linear guide ring

14a linear guide projections

14b relative rotation guide projections

14c relative rotation guide projections

14d circumferential groove

14e guide slots

14e-1 circumferential slot portions

14e-2 circumferential slot portions

14e-3 lead slot portion

14f first linear guide grooves

14g second linear guide grooves

15 third external barrel (rotatable ring)

15a rotation transfer projections

15b engaging projections

15c spring-engaging recesses

15d relative rotation guide projections

15e circumferential groove

15f rotation transfer grooves

17 roller-biasing spring

17a roller pressing protrusions

18 helicoid ring (rotatable ring)

18a male helicoid

18b rotational sliding projections

18c spur gear portion

18d rotation transfer recesses

18e engaging recesses

18f spring insertion recesses

18g circumferential groove

21 CCD holder

21a cam bar (optical element retracting mechanism)

21b stop surface

21c retracting cam surface

21d removed-position holding surface

21e guide key

21f recessed oblique surface

22 stationary barrel

22a female helicoid

22b linear guide grooves

22c lead grooves

22d rotational sliding grooves

22e stop-member insertion hole

22f cylindrical portion

22g 22h cutout portions

24 biasing springs for biasing the first lens group

25 separating-direction biasing springs

26 barrel stop member

28 zoom gear

29 zoom gear shaft

30 viewfinder drive gear

31 rollers for the first lens group

32 roller followers of the cam ring

32a roller set screws

33 pivot shaft for the second lens group

33a flange

34X first eccentric shaft (optical axis position adjustment device)

34X-a large diameter portion

34X-b front eccentric pin

34X-c rear eccentric pin

34X-d screwdriver engaging recess

34Y second eccentric shaft (optical axis position adjustment device)

34Y-a large diameter portion

34Y-b front eccentric pin

34Y-c rear eccentric pin

34Y-d screwdriver engaging recess

35 rotation limit shaft

35a large diameter portion

35b eccentric pin (stop)

35c screwdriver engaging recess

36 37 second lens frame support plates (optical axis position adjustment device)

36a 37a first vertically-elongated hole

36b 37b pivot hole

36c 37c cam-bar insertable hole

36d 37d screw hole

36e 37e horizontally-elongated hole

36f 37f second vertically-elongated hole

36f′ 37f′ obliquely-elongated hole

36g spring engaging recess

37g guide key insertable recess

38 axial-direction pressing spring

39 second-lens-frame returning spring

39a front spring end

39b rear spring end

40 rear torsion coil spring (optical element retracting

mechanism)

40a front stationary spring end

40b rear movable spring end

51 AF lens frame (third lens frame)

51a 51b guide holes

51c forwardly-projecting lens holder portion

51c1 front end surface

51c2 opening

51c3 51c4 51c5 51c6 side surfaces

51d 51e guide arm portions

51f forward protrusion

51g inclined contacting surface

51h recessed oblique surface

51i recess

52 53 AF guide shafts

54 AF nut

55 AF-frame biasing spring

60 CCD (solid-state image pick-up device)

61 sealing member

62 CCD base plate

64 fixing-ring set screws

66 support-plate set screw

66a threaded shaft portion

66b screwdriver engaging recess

70 digital camera

71 zoom lens

72 camera body

73 filter holder

74 reduction gear train box

75 lens-drive-control FPC board

76 shutter unit

77 exposure control FPC board

77a first straight portion

77b loop-shaped turning portion

77c second straight portion

77d third straight portion

77e terminal end

80 viewfinder unit

81a objective window plate

81b 81c movable power-varying lenses

81d prism

81e eyepiece

81f eyepiece window plate

82 guide shaft

101 lens barrier cover

102 barrier blade holding plate

103 barrier blade drive ring

104 105 barrier blades

106 barrier blade biasing springs

107 drive ring biasing spring

120 base plate

120a circular aperture

120b shutter-actuator support portion

120b1 accommodation recess

120c diaphragm-actuator support member

120c1 projecting portion

121 holding plate

122 diaphragm-actuator support cover

122a accommodation recess

123 cover ring

125 partition plate

125a circular aperture

126 blade-holding plate

126a circular aperture

127 blade association mechanism

129a 129b 129c set screws

131 shutter actuator

131a drive arm

132 diaphragm actuator

132a drive arm

140 control circuit

150 zoom motor

160 AF motor

【TITLE OF THE DOCUMENT】 ABSTRACT

【ABSTRACT】

【OBJECTIVE】

It is an object of the present invention to provide a photographing lens barrel which is capable of retracting an optical element of a photographing optical system to a position deviating from the photographing optical axis of the photographing optical system, wherein at least two actuators for actuating exposure control components are placed in the lens barrel in a space-saving manner.

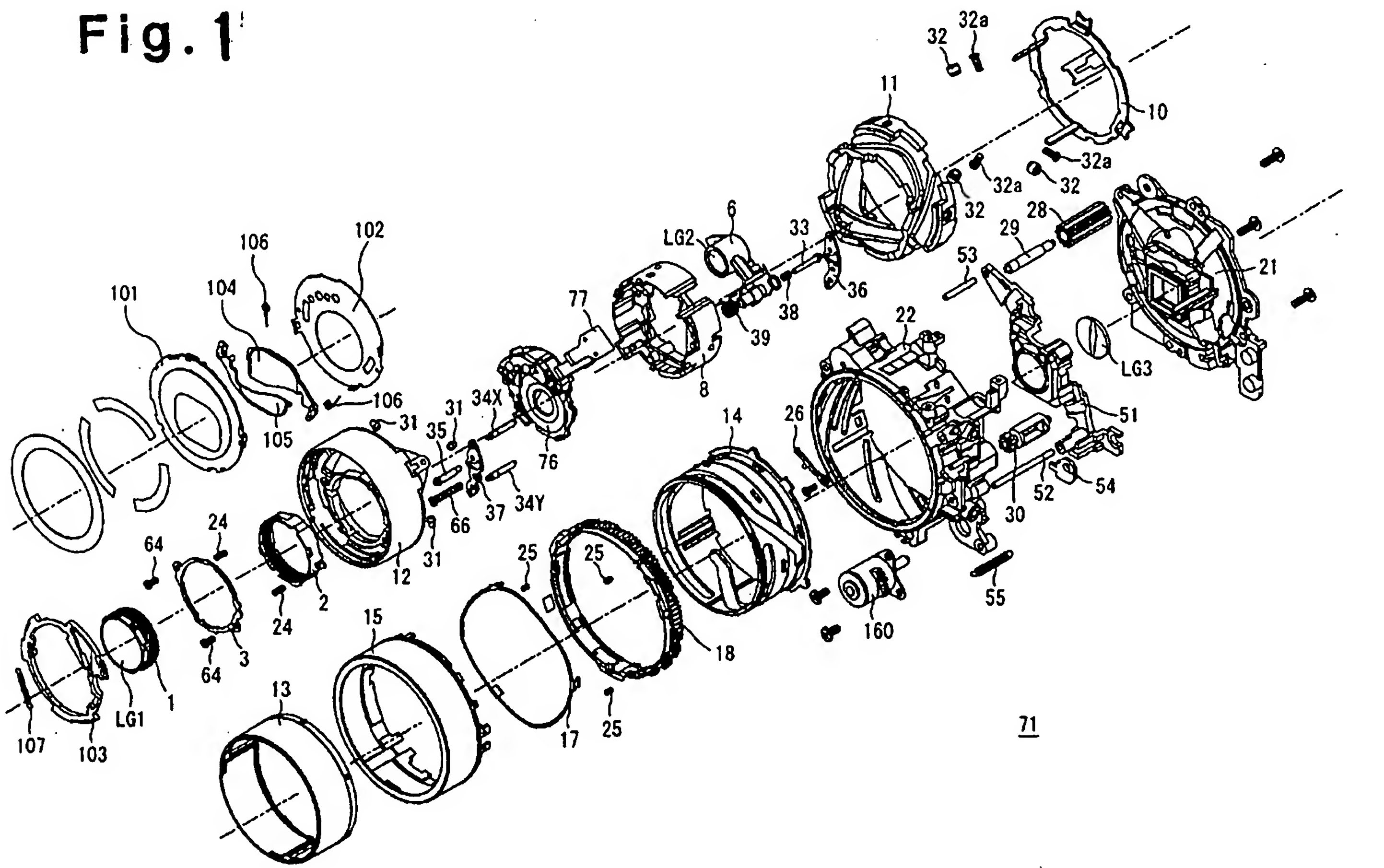
【CONSTITUTION】

Disclosed is a lens barrel including: a front lens group, a middle lens group, a rear lens group and an exposure control component which are positioned on a photographing optical axis in a ready-to-photograph state of the lens barrel; and a ring member which accommodates the front lens group, the middle lens group, the rear lens group and the exposure control component in a retracted state of the lens barrel; and at least two actuators for actuating the exposure control component, wherein the photographing optical axis is parallel to an axis of the optical-element-accommodating ring member, wherein, when the lens barrel changes from the ready-to-photograph state to the retracted state, the front lens group and the rear lens group are moved rearward while approaching each other along the photographing optical axis, the middle lens group is retracted to a radially retracted position on an opposite side of the axis of the optical-element-accommodating

ring member from the photographing optical axis, and the middle lens group is moved rearward along the photographing optical axis so that the middle lens group is positioned in an off-axis space radially outside an on-axis space in which the rear lens group is positioned, wherein one of the two actuators is positioned inside the optical-element-accommodating ring member in a first space between an inner peripheral surface of the optical-element-accommodating ring member and an outer edge of the front lens group accommodated in the optical-element-accommodating ring member, and wherein the other of the two actuators is positioned inside the optical-element-accommodating ring member in a second space between an inner peripheral surface of the optical-element-accommodating ring member and an outer edge of the rear lens group accommodated in the optical-element-accommodating ring member, and is positioned outside a moving path of the middle lens group at an axial position different from an axial position of the one of the two actuators in the photographing optical axis direction.

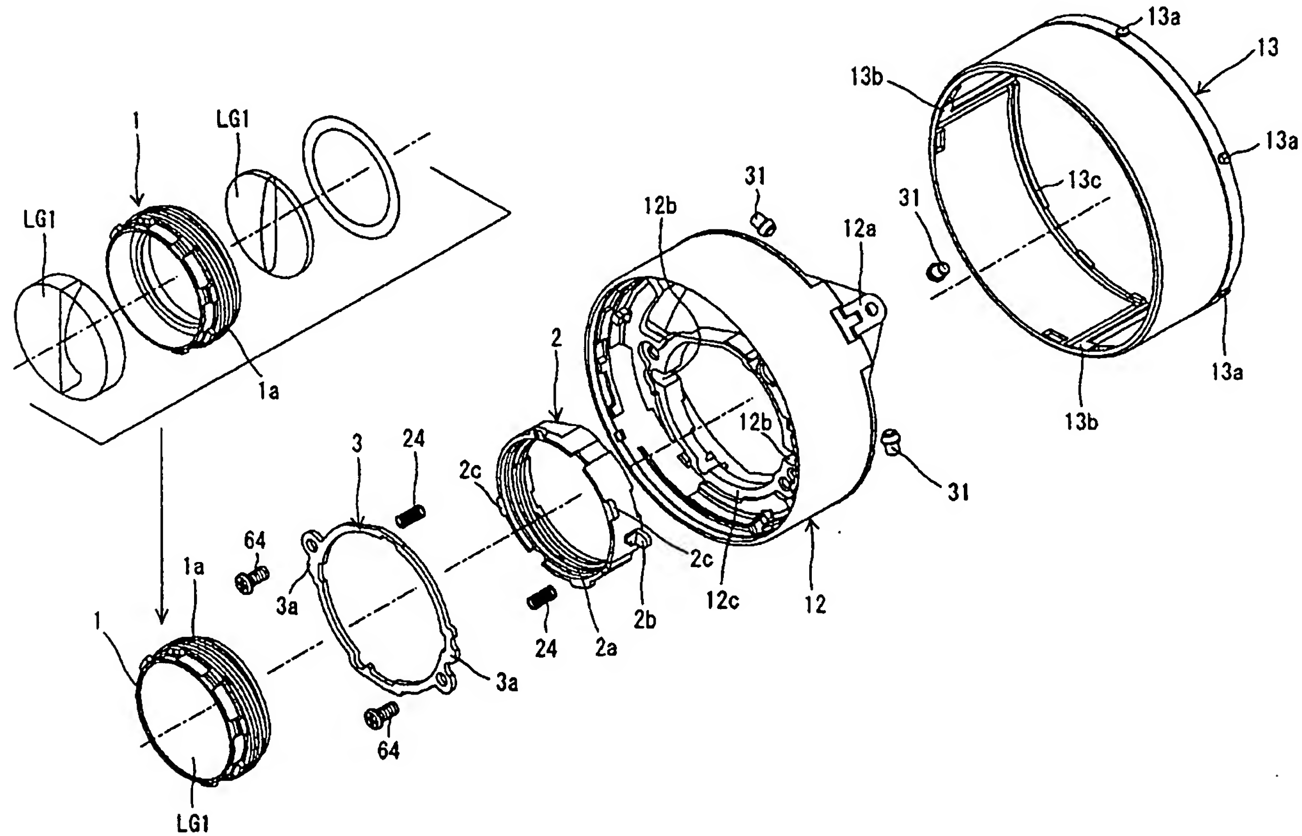
【SELECTED FIGURE】 Figure 55

Fig. 1



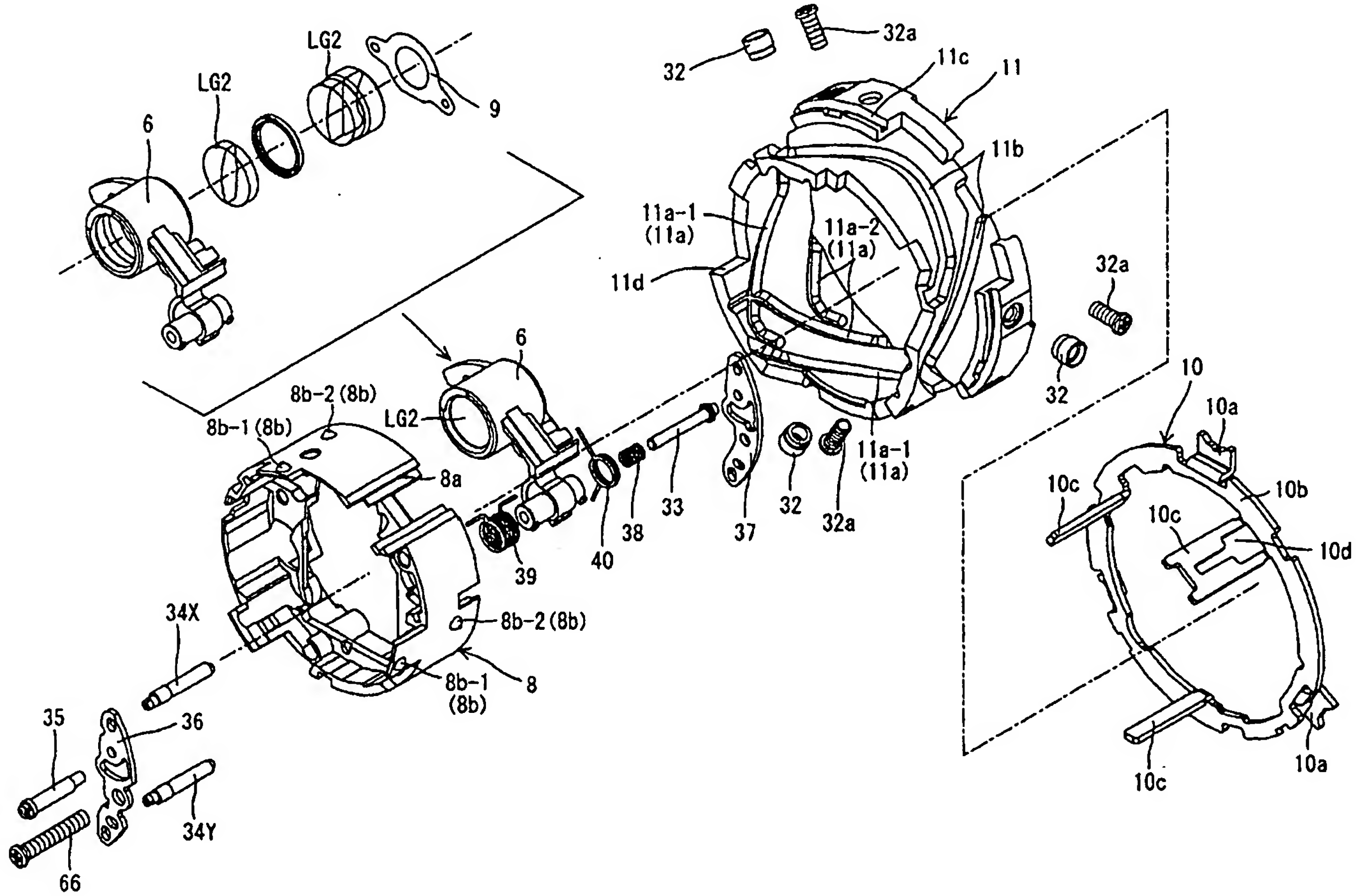
101
102
104
105
106
107
103
LG1
1
2
3
24
64
12
13
15
17
18
25
31
35
34X
34Y
37
66
76
77
8
LG2
6
33
36
38
39
11
14
26
22
160
55
30
52
54
51
53
29
28
LG3
21
10
32
32a
71

Fig. 2



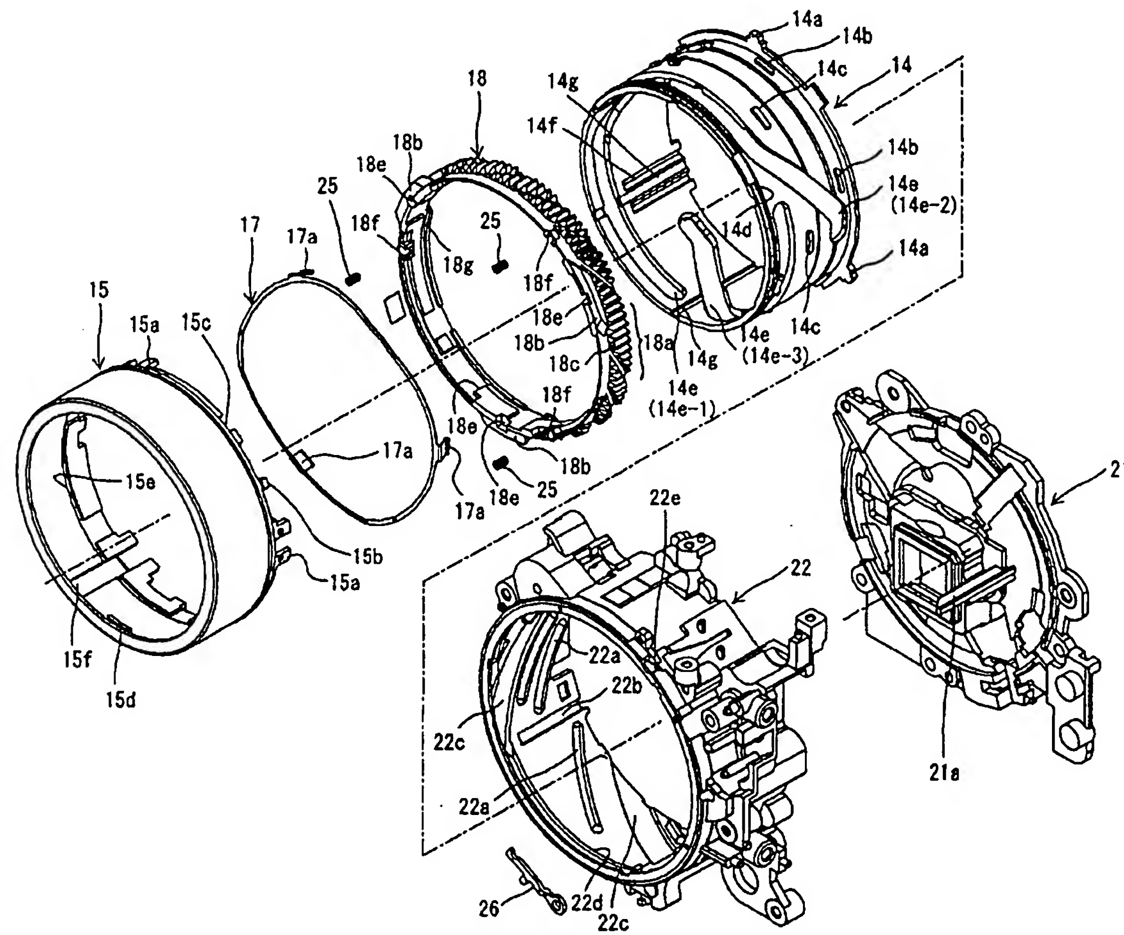
LG1
1
LG1
1a
1
1a
LG1
3a
64
3
24
3a
64
2c
2
24
2a
2b
2c
12c
12b
12b
12
12a
31
31
31
13b
13c
13b
13
13a
13a
13a

Fig. 3



6
LG2
LG2
9
32
32a
11c
11
11b
11a-1
(11a)
11a-2
(11a)
11d
32a
32
6
8b-2 (8b)
8b-1 (8b)
LG2
8a
39
40
38
33
37
32
32a
11a-1
(11a)
10
10a
10c
10b
10c
10d
34X
8b-2 (8b)
8b-1
(8b)
8
35
36
34Y
66
10c
10a

Fig.4



14a
14b
14c
14
14g
14f
14b
14e
(14e-2)
14d
14a
14c
14e
(14e-3)
14g
14e
(14e-1)
18
18b
18e
18f
18g
25
18f
18e
18b
18c
18a
18f
18e
18b
25
18e
17
17a
17a
17a
15
15a
15c
15e
15b
15a
15f
15d
21
21a
22e
22
22a
22b
22c
22a
26
22d
22c

Fig.5

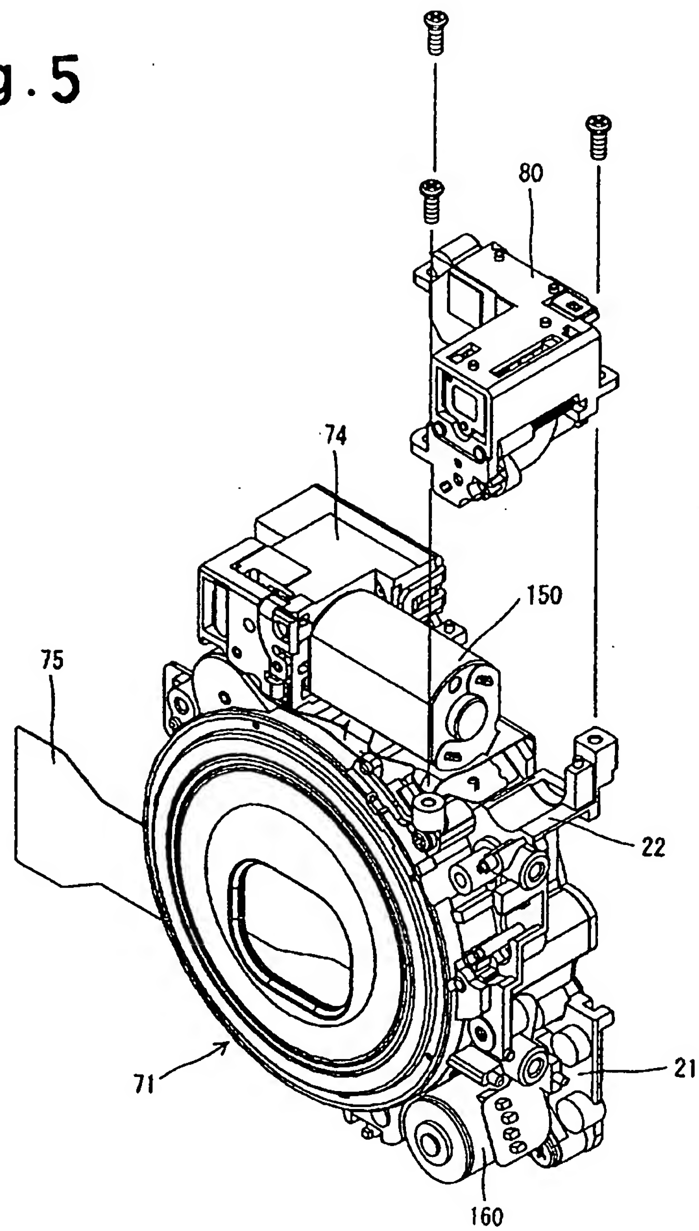


Fig. 6

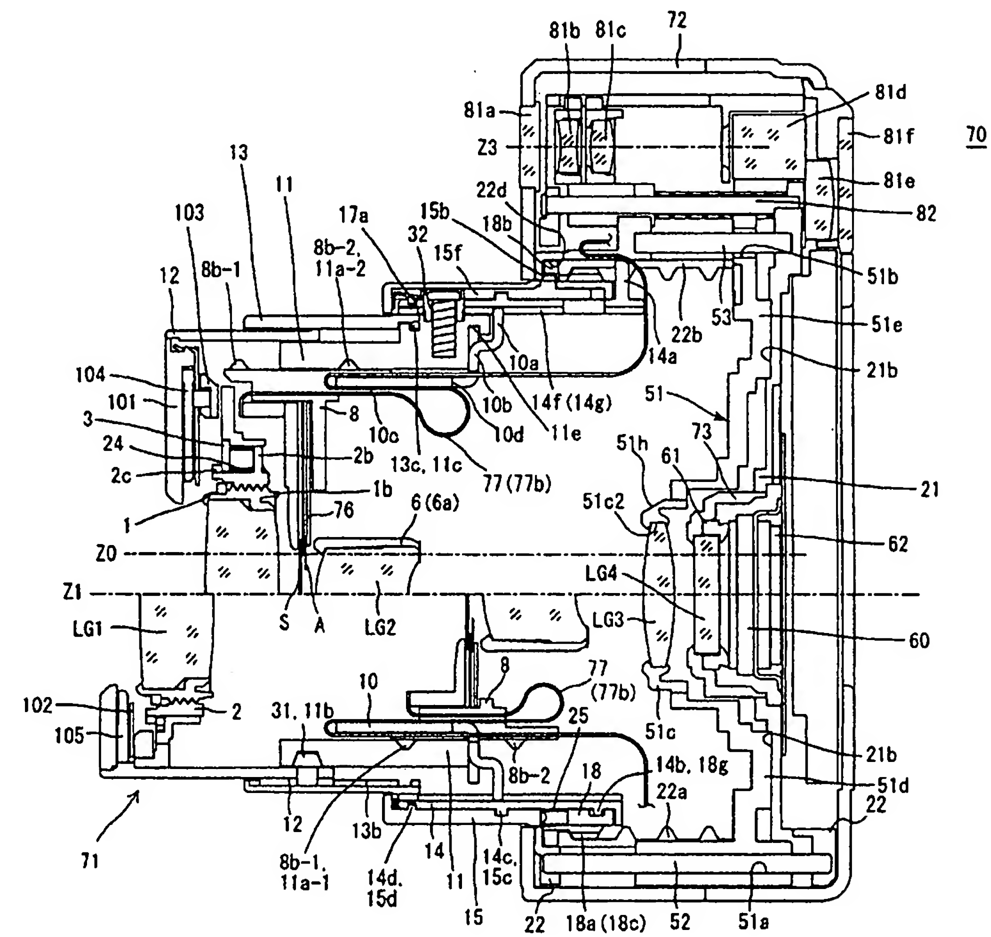
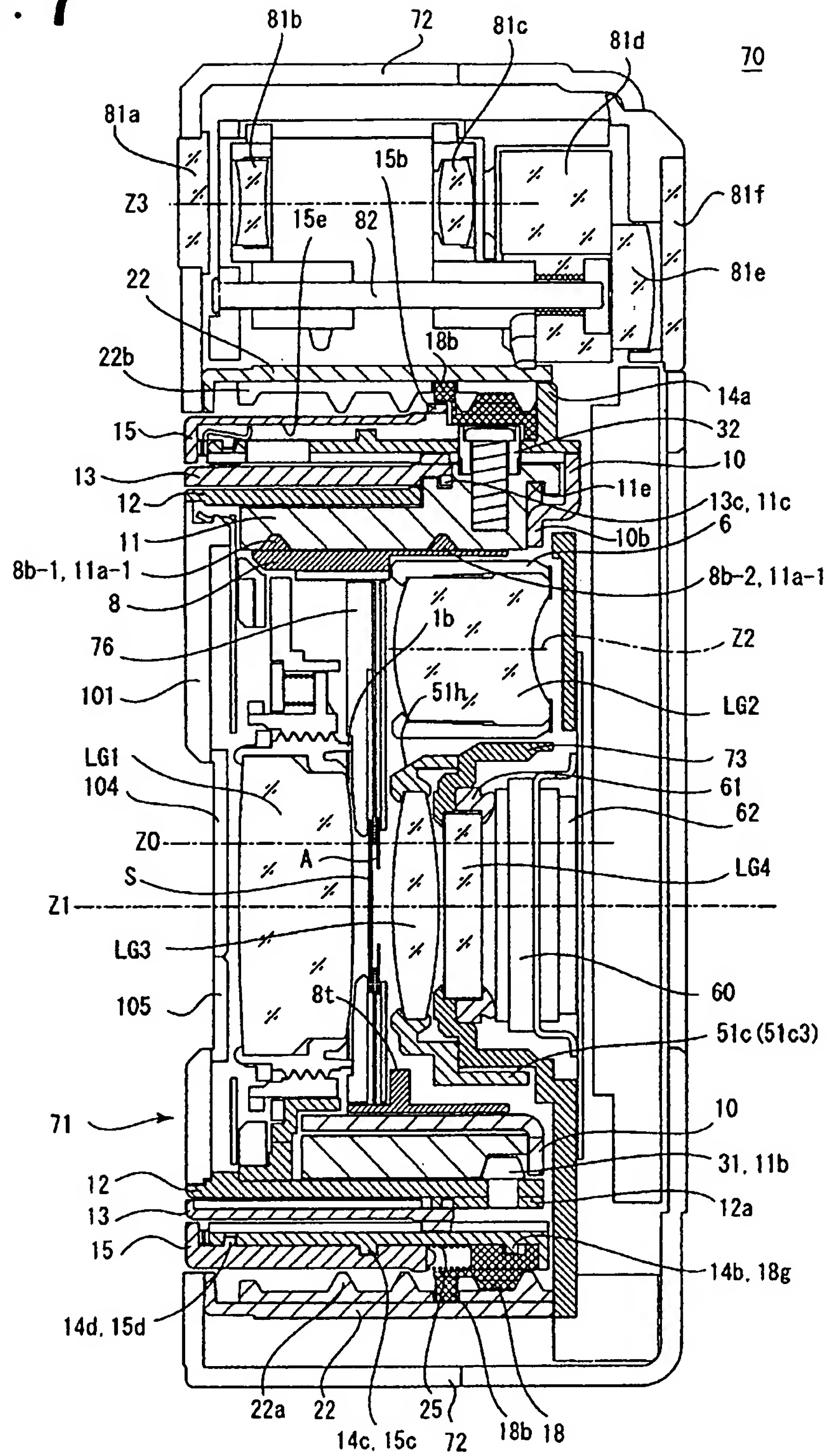

70
72
81b 81c
81a
81d
81f
Z3
81e
82
22d
18b
15b
17a
32
15f
51b
53
22b
51e
14a
10a
14f (14g)
21b
13
11
103
12
8b-1
8b-2,
11a-2
104
101
8
10c
10b
10d
11e
3
24
2c
2b
1b
13c, 11c
77 (77b)
1
76
6 (6a)
51
73
61
51h
21
51c2
62
Z0
Z1
LG1
S
A
LG2
LG4
LG3
60
10
8
77
(77b)
102
105
2
31, 11b
25
51c
8b-2
18
14b, 18g
22a
21b
51d
22
71
12
13b
8b-1,
11a-1
14d,
15d
14
11
14c,
15c
15
22
18a (18c)
52
51a

Fig. 7



81b
72
81c
81d
70
81a
15b
Z3
15e
82
81f
22
81e
22b
18b
14a
15
32
10
13
11e
12
13c, 11c
11
6
10b
8b-1, 11a-1
8b-2, 11a-1
8
1b
76
Z2
101
51h
LG2
LG1
73
104
61
62
Z0
A
LG4
S
Z1
LG3
8t
60
105
51c (51c3)
10
71
31, 11b
12
12a
13
15
14b, 18g
14d, 15d
22a
22
14c, 15c
25
72
18b
18

Fig. 8

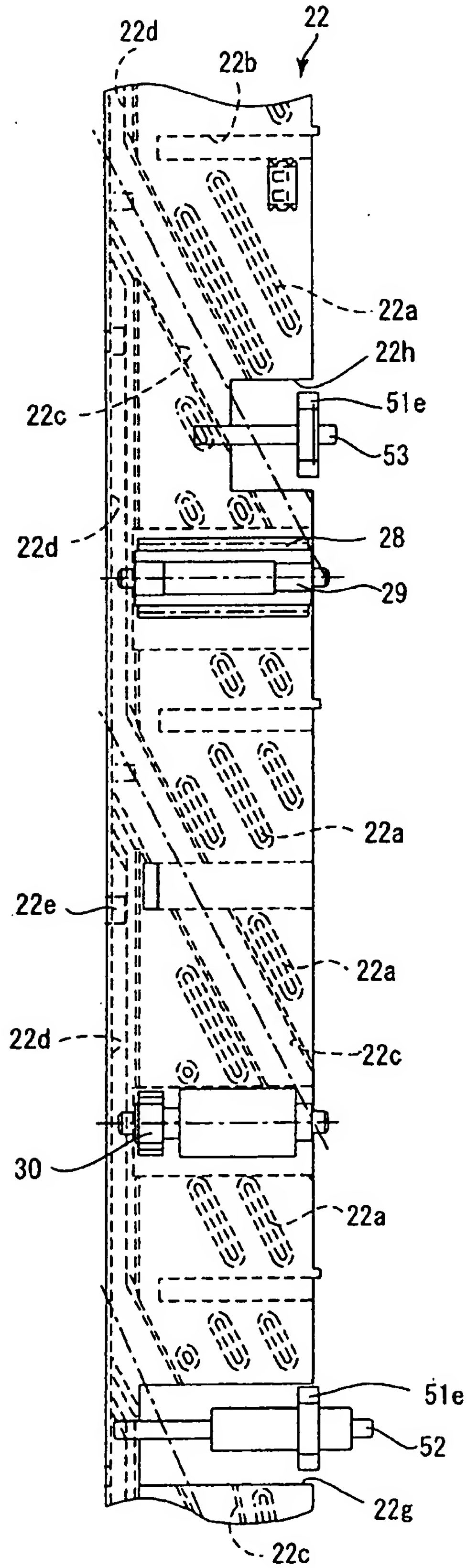

22
22d
22b
22a
22h
51e
22c
53
22d
28
29
22a
22e
22a
22d
22c
30
22a
51e
52
22g
22c

Fig. 9

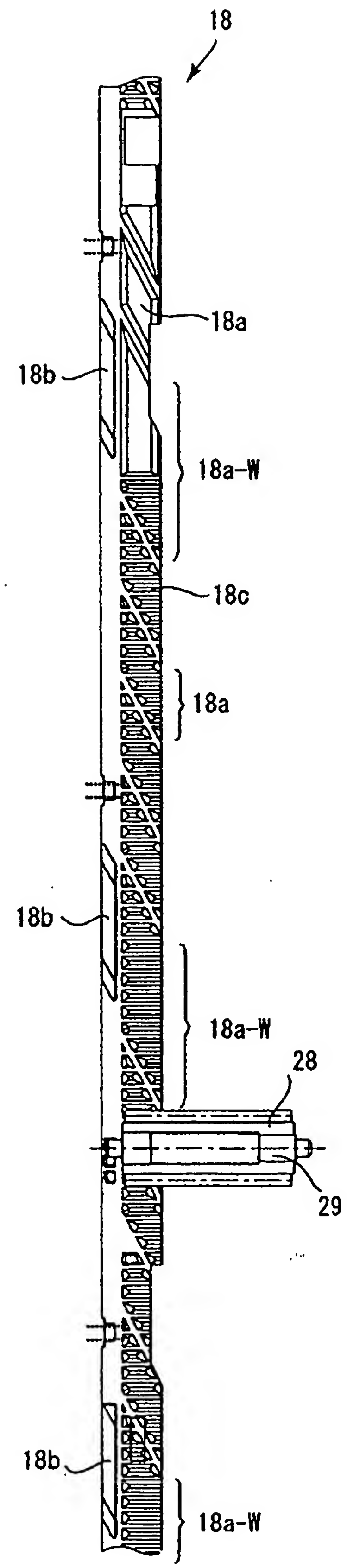
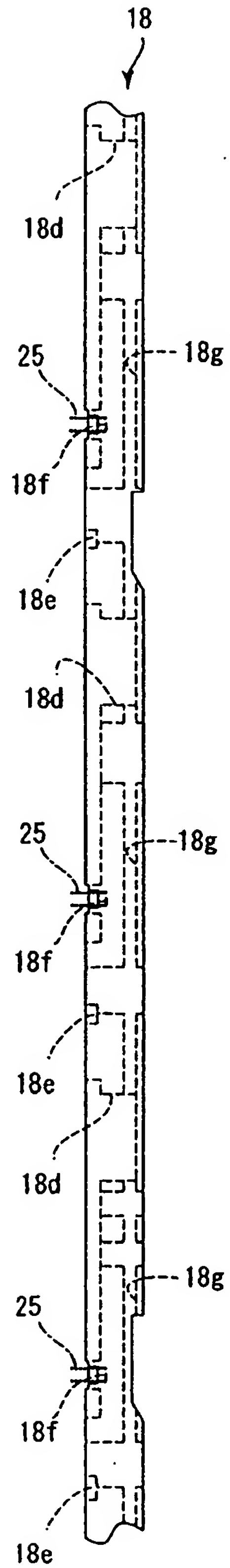


Fig.10



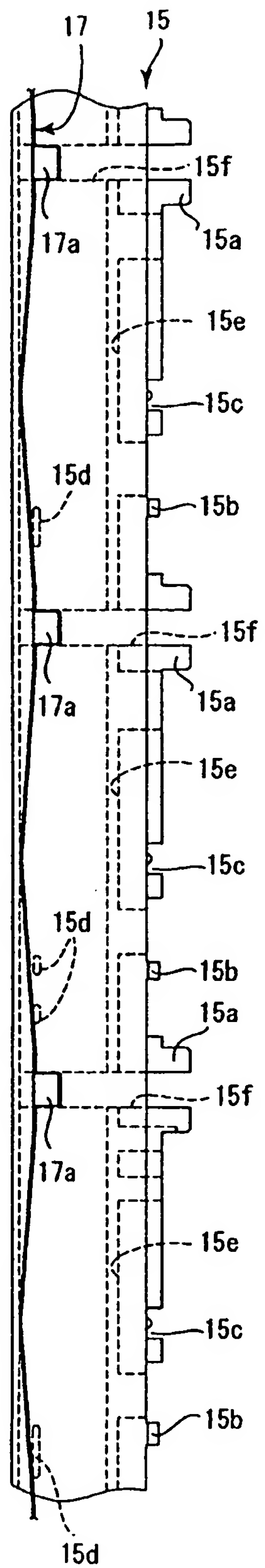

17
15
15f
17a
15a
15e
15c
15d
15b
15f
17a
15a
15e
15c
15d
15b
15a
15f
17a
15e
15c
15b
15d

Fig.11

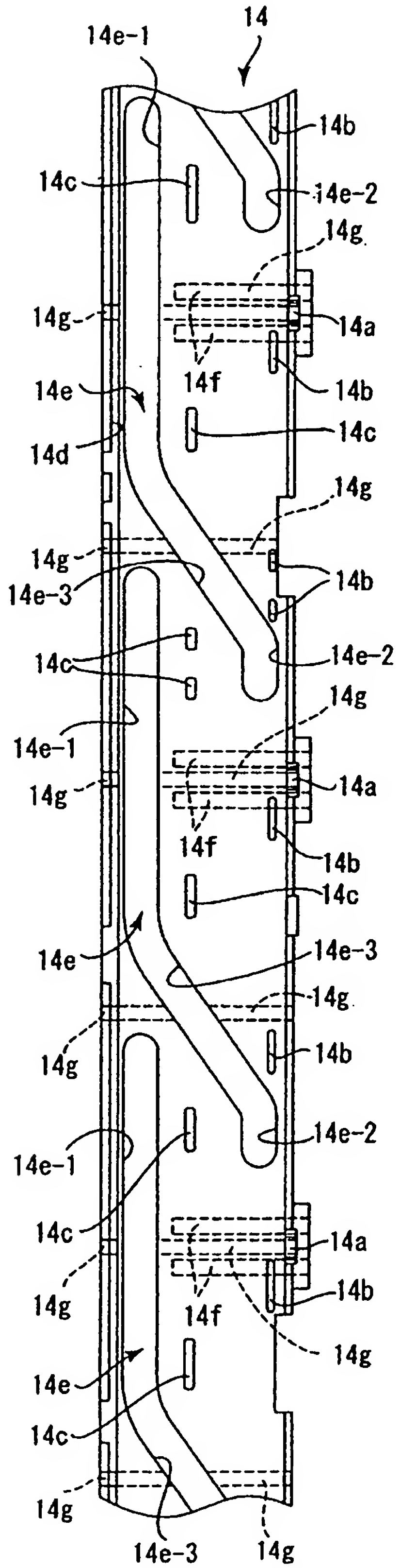

14
14e-1
14b
14c
14e-2
14g
14g
14a
14f
14b
14e
14d
14c
14g
14g
14b
14e-3
14c
14e-2
14g
14e-1
14g
14a
14f
14b
14c
14e
14e-3
14g
14g
14b
14e-1
14e-2
14c
14a
14g
14b
14f
14g
14e
14c
14g
14e-3
14g

Fig.12

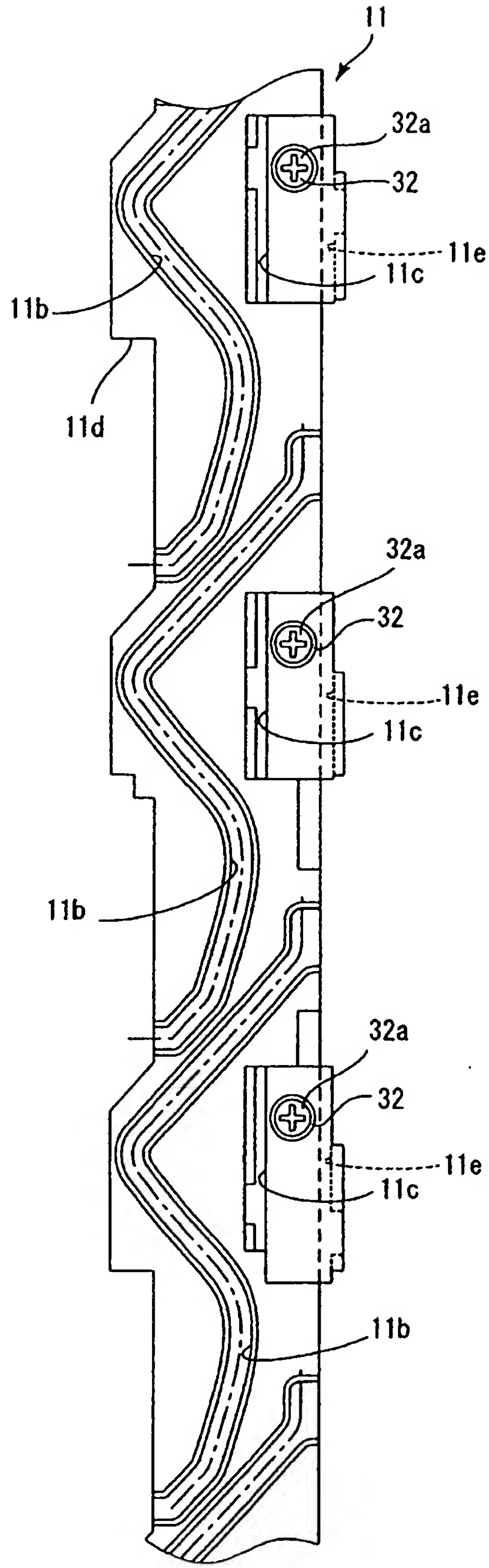
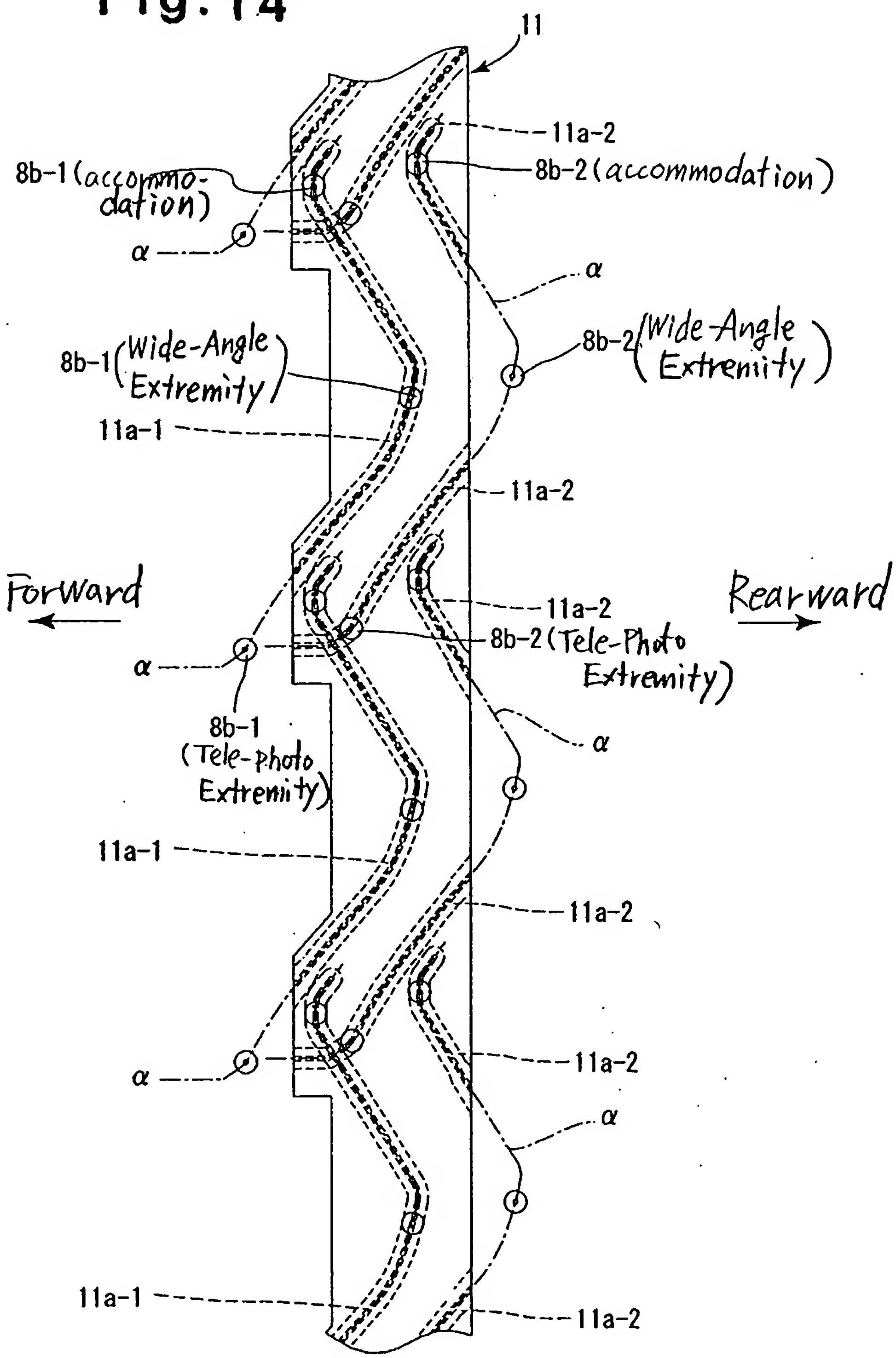


Fig.13

Fig. 14


11
11a-2
8b-1 (accommodation)
8b-2 (accommodation)
α
α
8b-1 (Wide-Angle Extremity)
8b-2 (Wide-Angle Extremity)
11a-1
11a-2
Forward
Rearward
11a-2
α
8b-2 (Tele-Photo Extremity)
8b-1 (Tele-photo Extremity)
α
11a-1
11a-2
α
11a-2
α
11a-1
11a-2

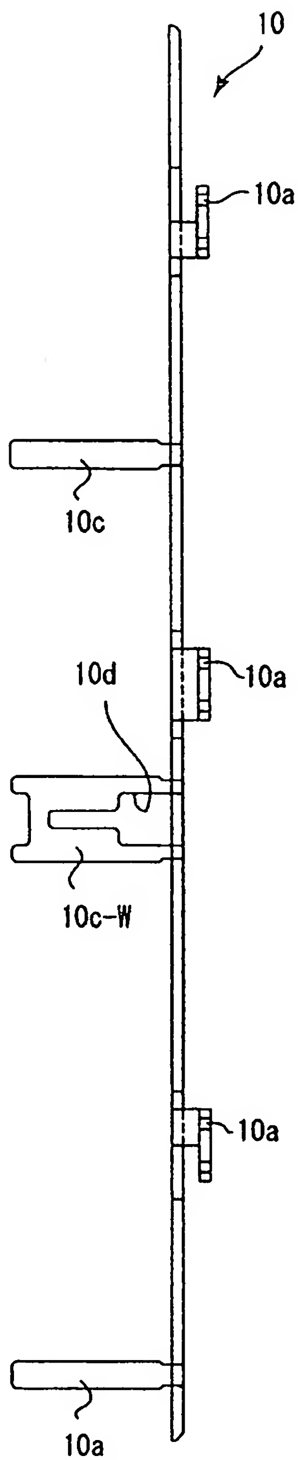


Fig. 15

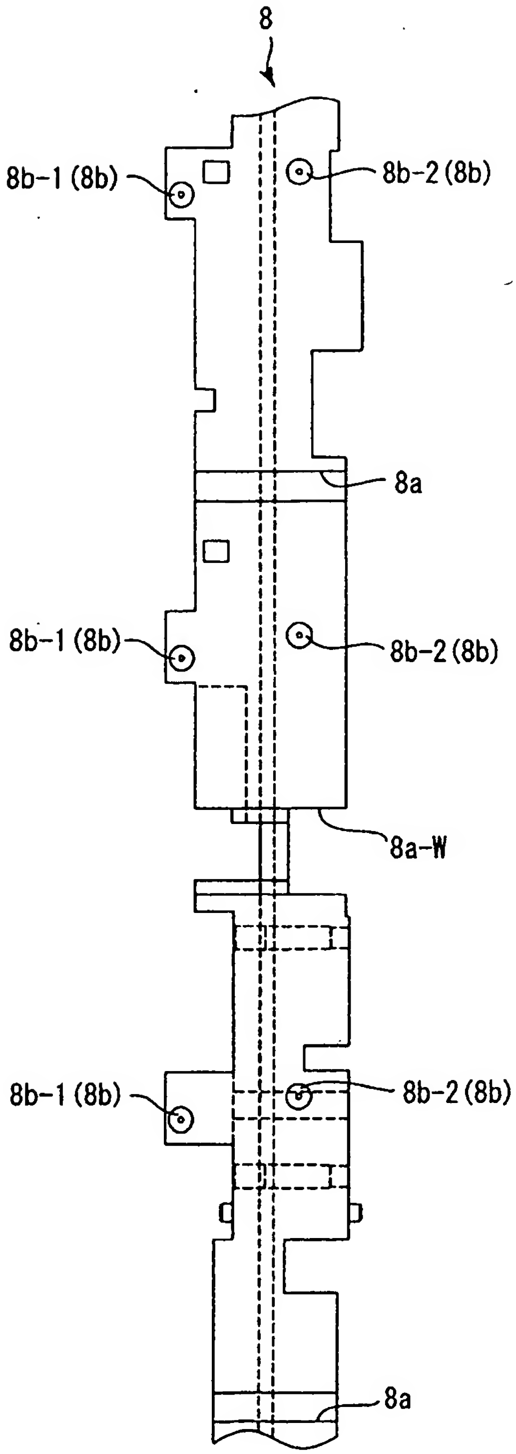


Fig.16

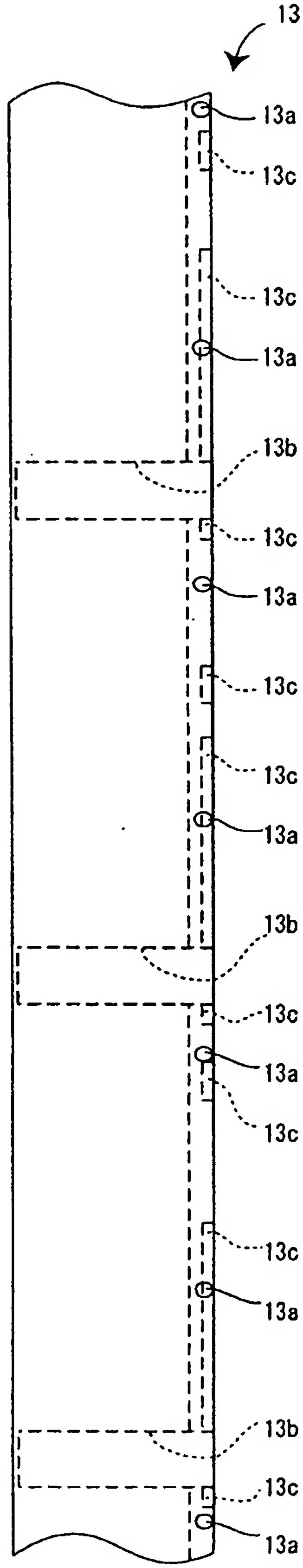

13
13a
13c
13c
13a
13b
13c
13a
13c
13c
13a
13b
13c
13a
13c
13c
13a
13b
13c
13a

Fig.17

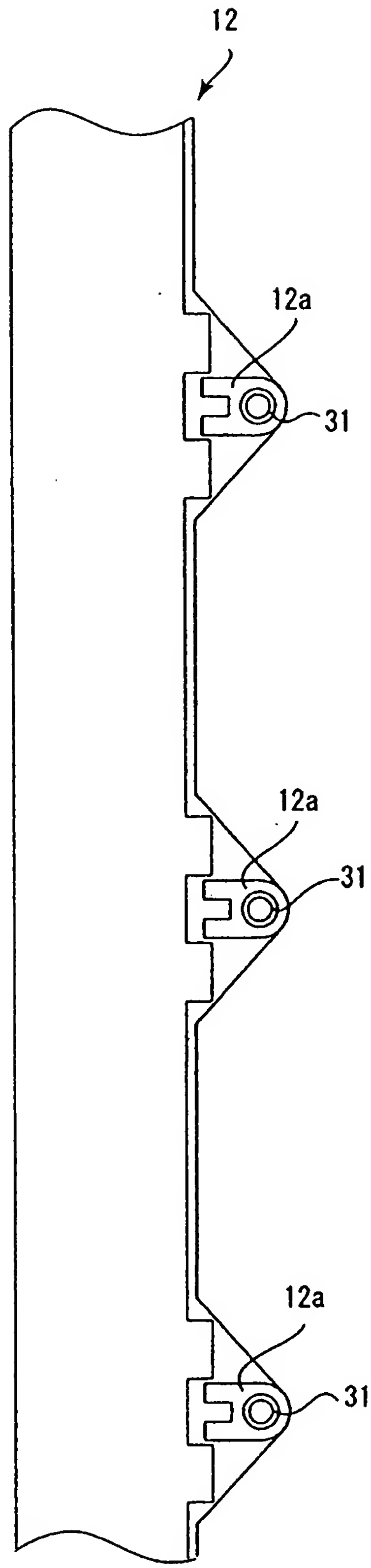
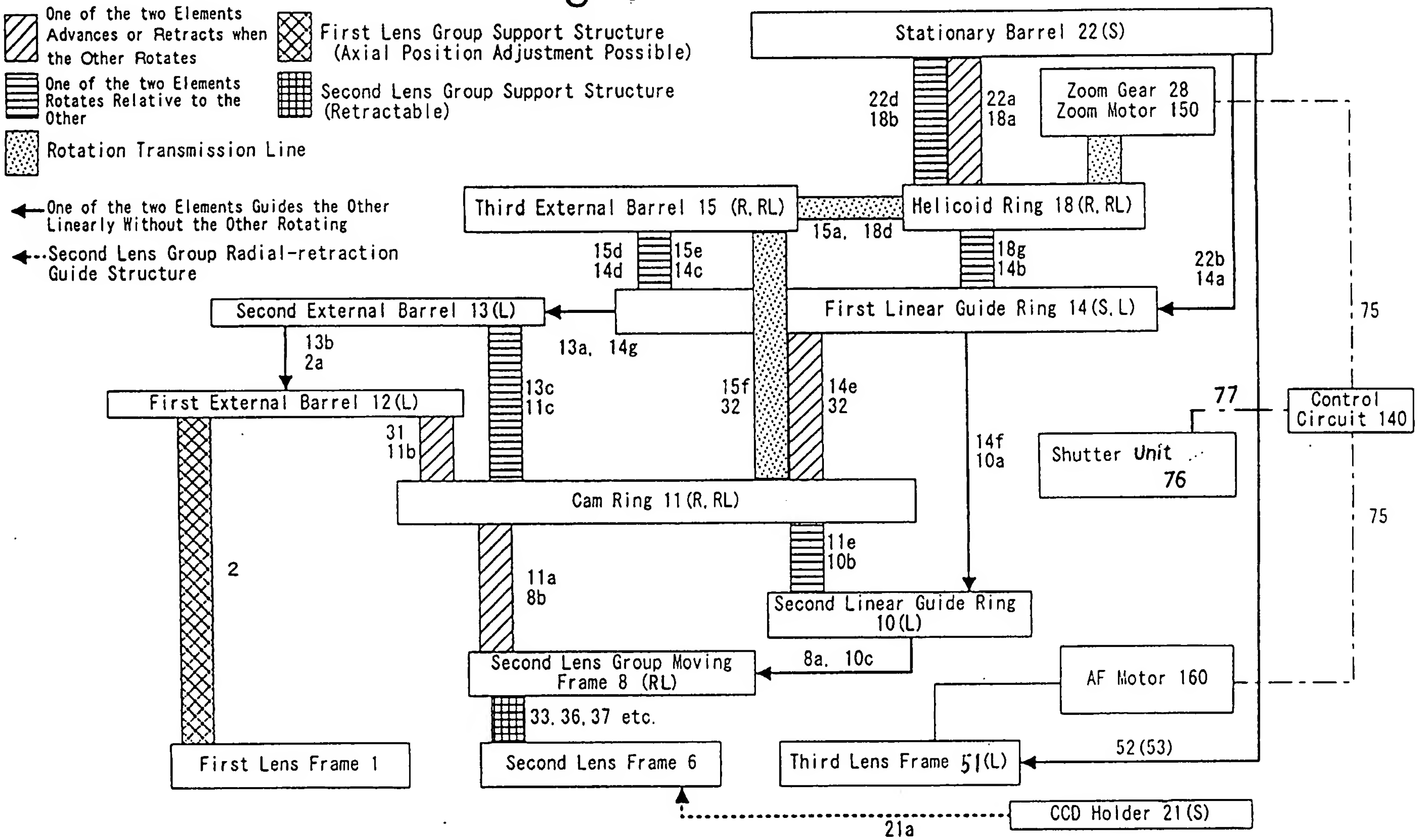


Fig.18

Fig. 19



One of the two Elements Advances or Retracts when the Other Rotates
One of the two Elements Rotates Relative to the Other
Rotation Transmission Line
First Lens Group Support Structure (Axial Position Adjustment Possible)
Second Lens Group Support Structure (Retractable)
One of the two Elements Guides the Other Linearly Without the Other Rotating
Second Lens Group Radial-retraction Guide Structure
Stationary Barrel 22(S)
Zoom Gear 28
Zoom Motor 150
22d
18b
22a
18a
Helicoid Ring 18(R, RL)
Third External Barrel 15 (R, RL)
15a, 18d
15d
14d
15e
14c
18g
14b
22b
14a
First Linear Guide Ring 14(S, L)
Second External Barrel 13(L)
13a, 14g
13b
2a
First External Barrel 12(L)
13c
11c
15f
32
14e
32
14f
10a
31
11b
Cam Ring 11(R, RL)
77
Control Circuit 140
Shutter Unit 76
75
75
2
11e
10b
11a
8b
Second Linear Guide Ring 10(L)
8a, 10c
Second Lens Group Moving Frame 8 (RL)
AF Motor 160
33, 36, 37 etc.
First Lens Frame 1
Second Lens Frame 6
Third Lens Frame 51(L)
52(53)
CCD Holder 21(S)
21a

Fig. 20

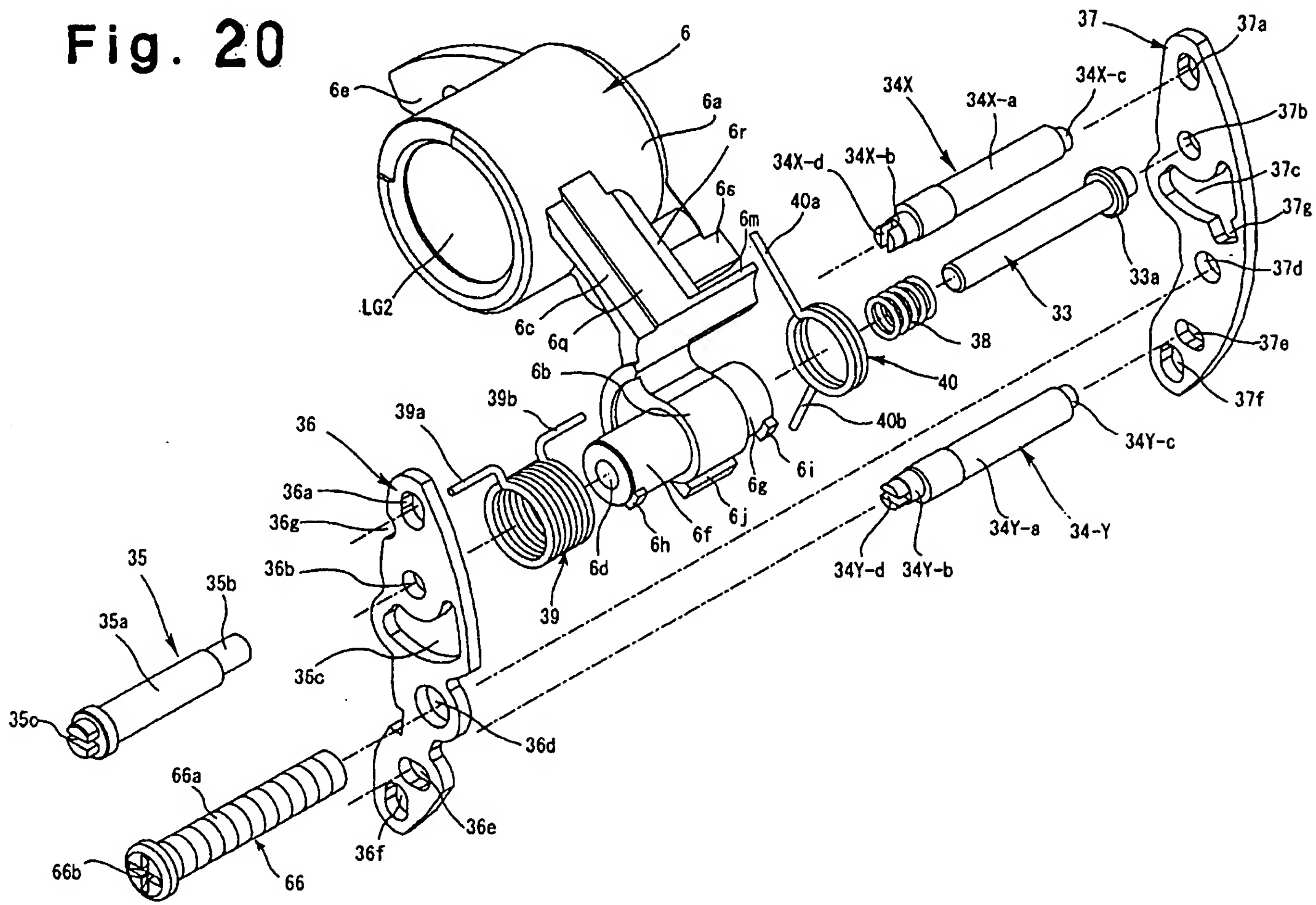
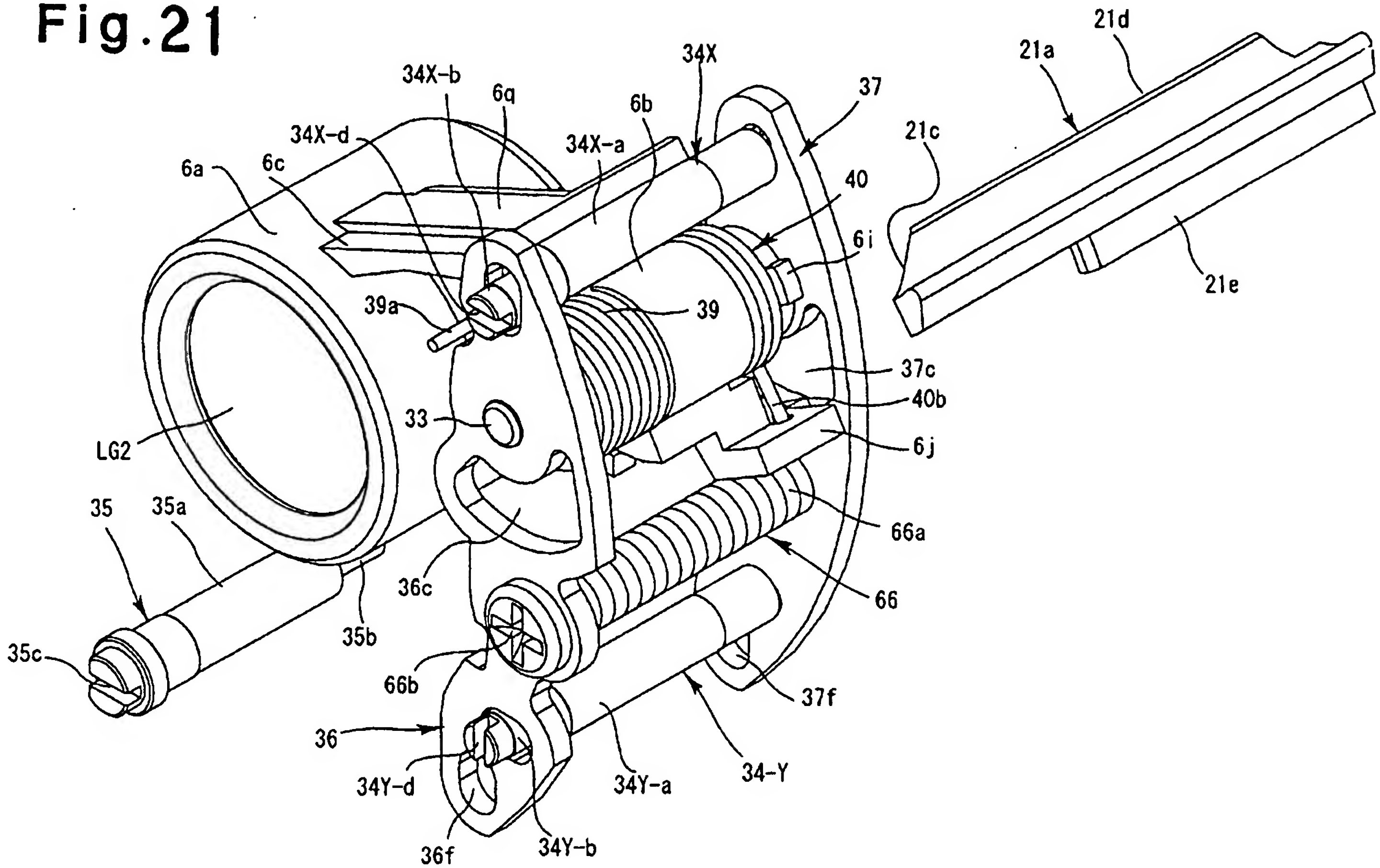
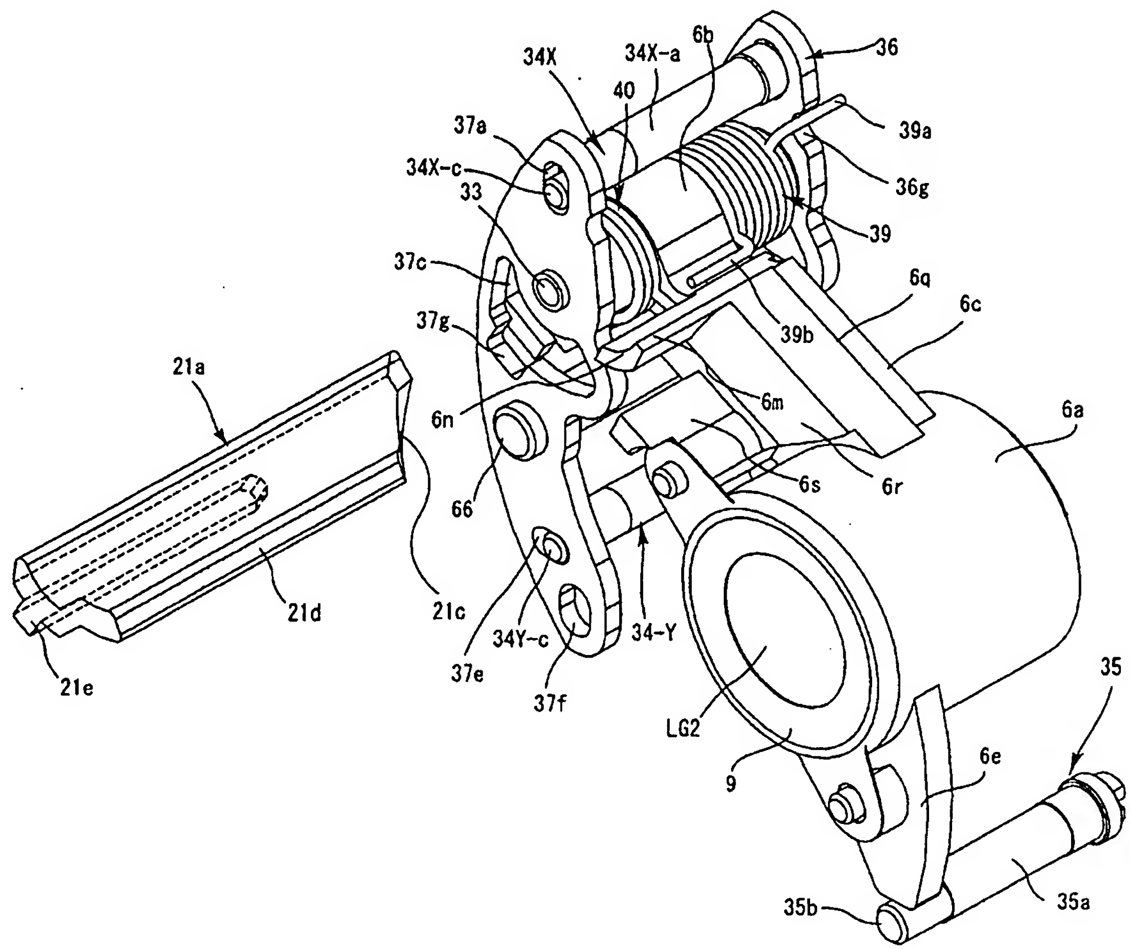

6
6e
6a
6r
6s
6m
6c
6q
6b
6d
6f
6h
6g
6j
6i
LG2
40a
40
40b
38
33
33a
34X
34X-a
34X-b
34X-c
34X-d
34-Y
34Y-a
34Y-b
34Y-c
34Y-d
37
37a
37b
37c
37g
37d
37e
37f
36
36a
36g
36b
36c
36d
36e
36f
39
39a
39b
35
35a
35b
35c
66
66a
66b

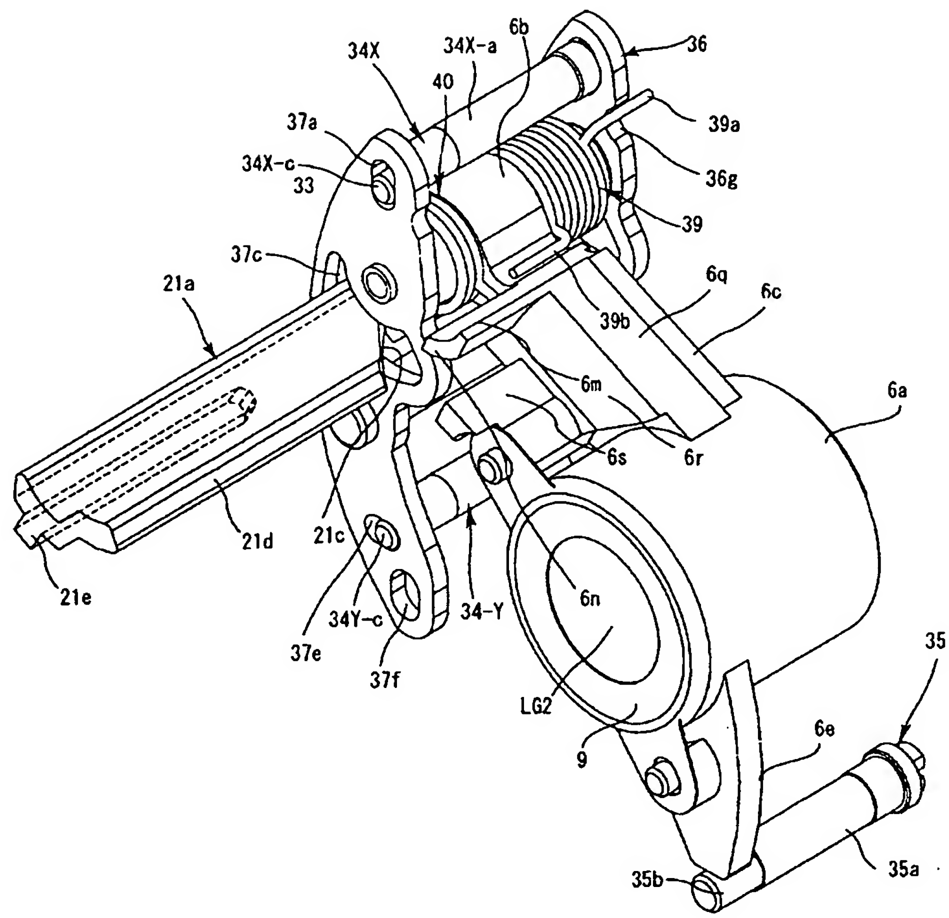
Fig.21



34X-b
6q
34X
37
21a
21d
21c
6b
34X-a
34X-d
6a
6c
40
6i
21e
39a
39
37c
40b
33
6j
LG2
66a
35
35a
36c
66
35c
35b
66b
37f
36
34Y-d
34Y-a
34-Y
36f
34Y-b

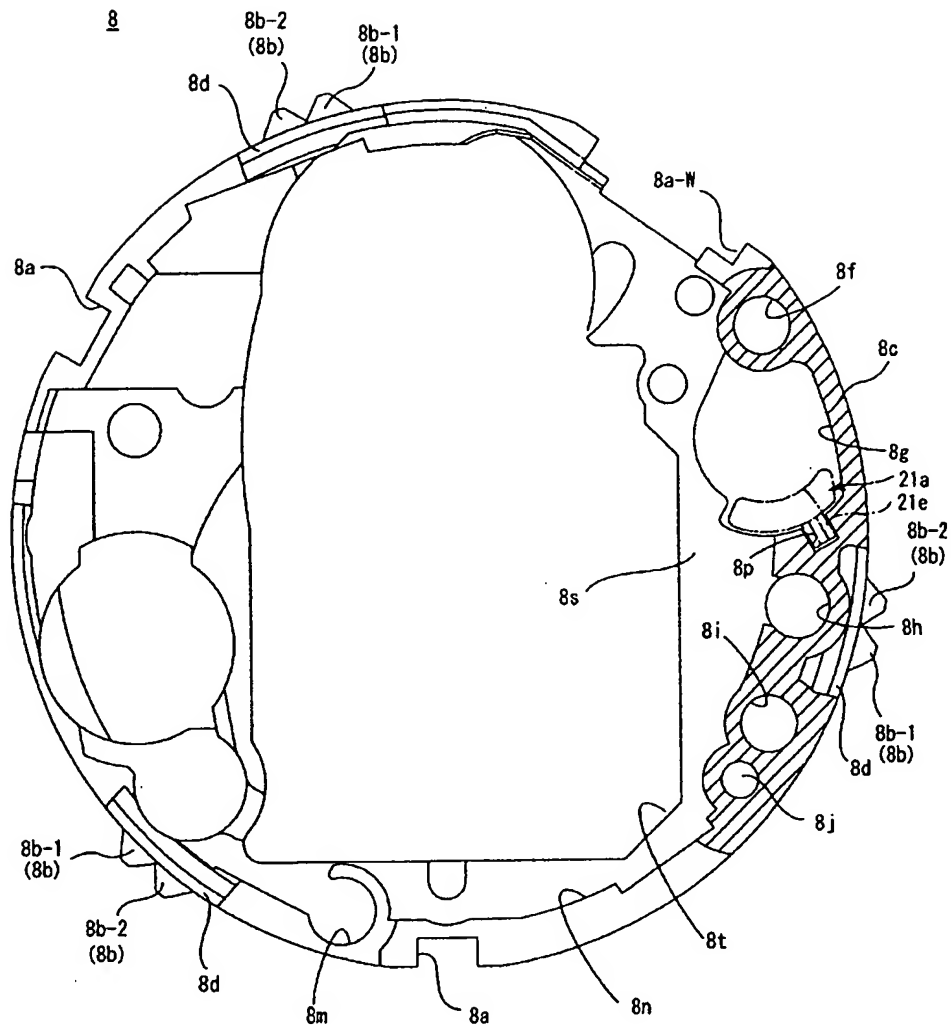
Fig.22


36
34X
34X-a
6b
40
39a
37a
34X-c
36g
33
39
37c
6q
37g
39b
6c
21a
6m
6n
6a
66
6s
6r
21d
21c
34Y-c
34-Y
37e
21e
37f
35
LG2
6e
9
35b
35a



34X
34X-a
6b
36
40
39a
37a
36g
34X-c
33
39
37c
6q
21a
39b
6c
6m
6a
6s
6r
21d
21c
21e
6n
34-Y
34Y-c
37e
37f
LG2
35
9
6e
35b
35a

Fig.23



8
8b-2
(8b)
8b-1
(8b)
8d
8a-W
8f
8a
8c
8g
21a
21e
8b-2
(8b)
8p
8s
8h
8i
8b-1
(8b)
8d
8j
8b-1
(8b)
8b-2
(8b)
8t
8d
8m
8a
8n

Fig.24

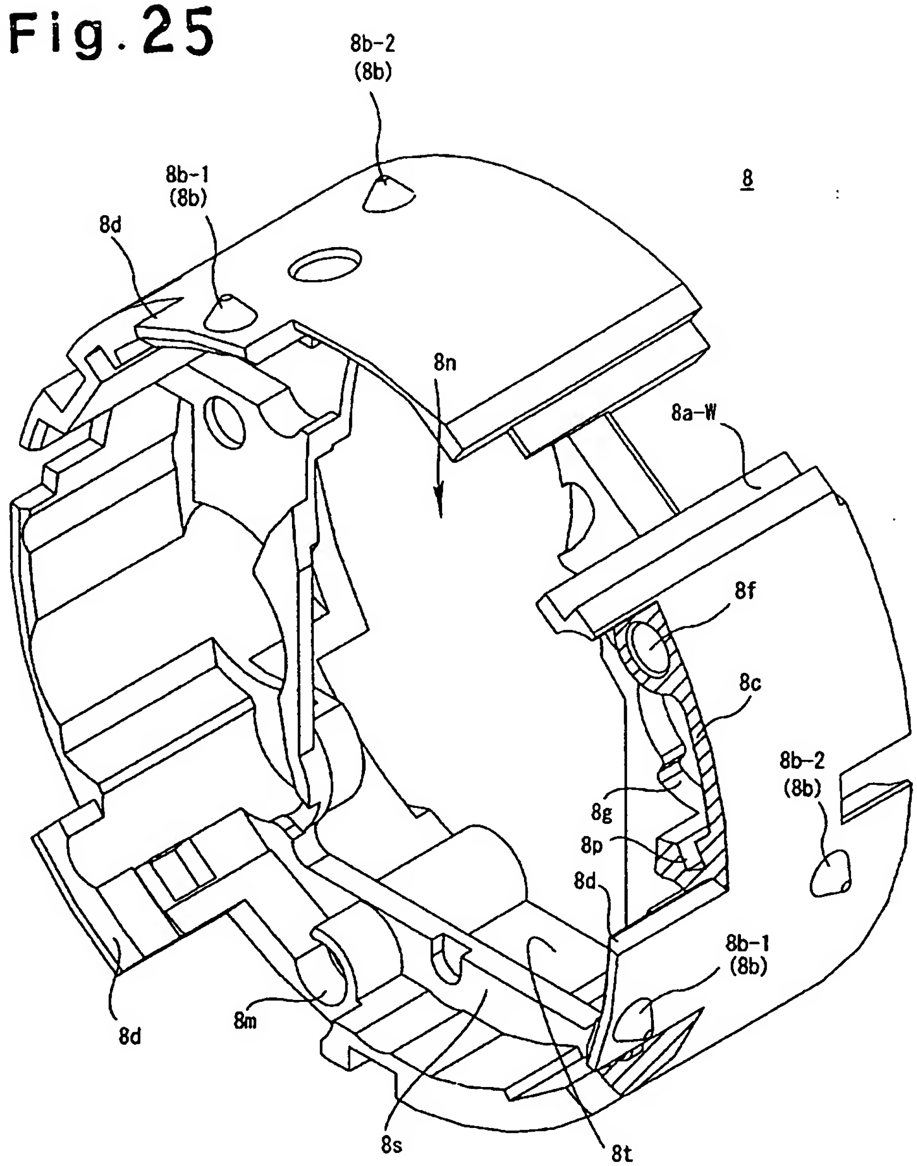
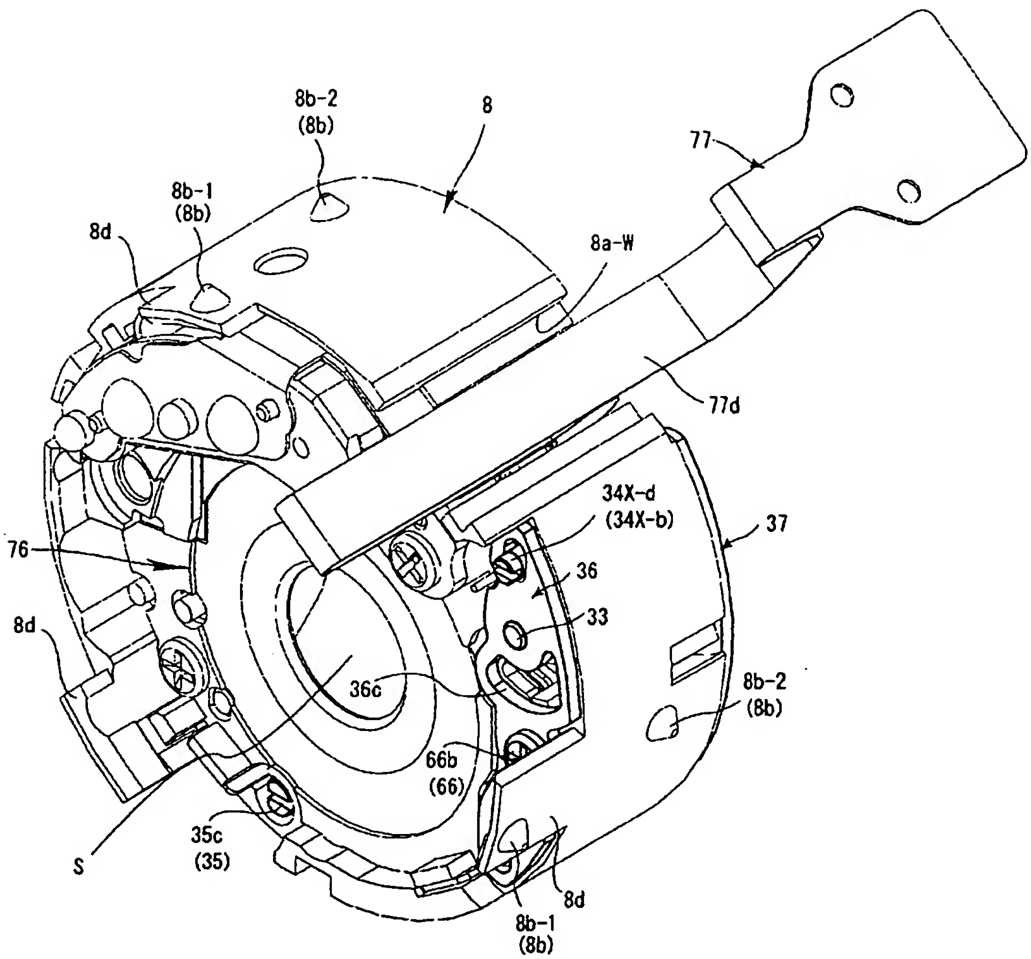


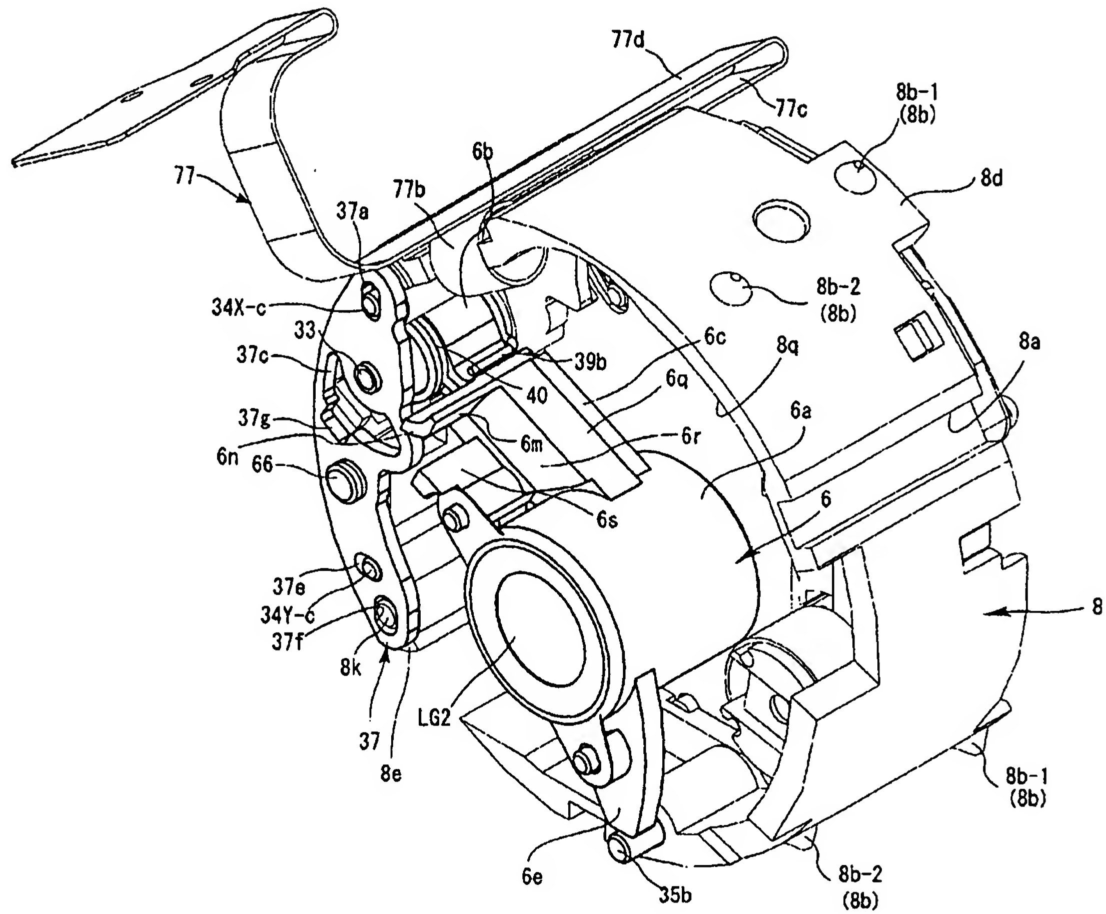
Fig.25



8b-2
(8b)
8
77
8b-1
(8b)
8d
8a-W
77d
34X-d
(34X-b)
37
76
36
33
8d
36c
8b-2
(8b)
66b
(66)
35c
(35)
S
8d
8b-1
(8b)

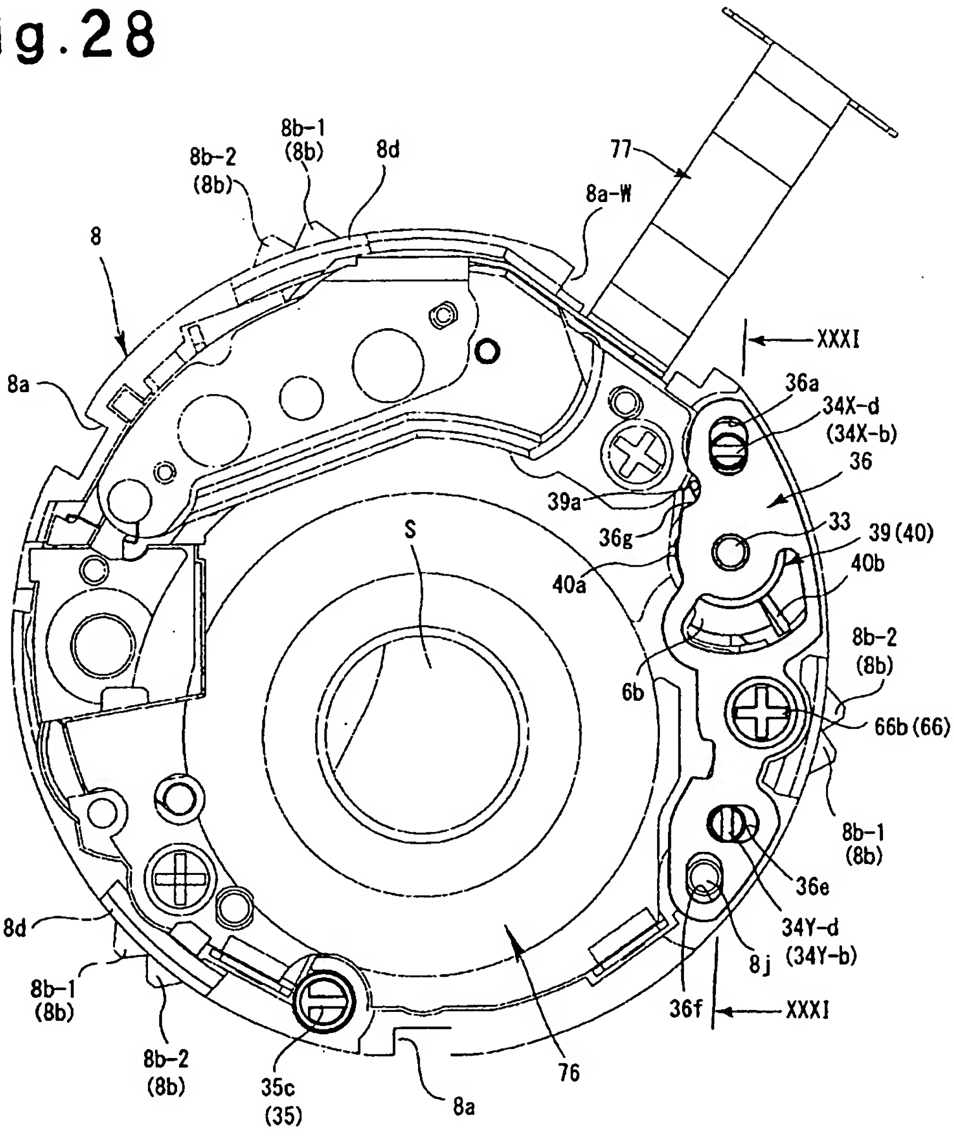
Fig.26

Fig.27



77d
77c
8b-1
(8b)
8d
77
37a
77b
6b
8b-2
(8b)
34X-c
33
6c
8q
8a
37c
39b
40
6q
37g
6m
6r
6a
6n
66
6s
6
37e
34Y-c
37f
8
8k
LG2
37
8e
8b-1
(8b)
6e
35b
8b-2
(8b)

Fig.28


77
8b-1
(8b)
8b-2
(8b)
8d
8a-W
8
8a
XXXI
36a
34X-d
(34X-b)
36
39a
36g
33
39(40)
40a
40b
S
6b
8b-2
(8b)
66b(66)
8b-1
(8b)
36e
34Y-d
(34Y-b)
8j
8d
8b-1
(8b)
8b-2
(8b)
36f
XXXI
35c
(35)
76
8a

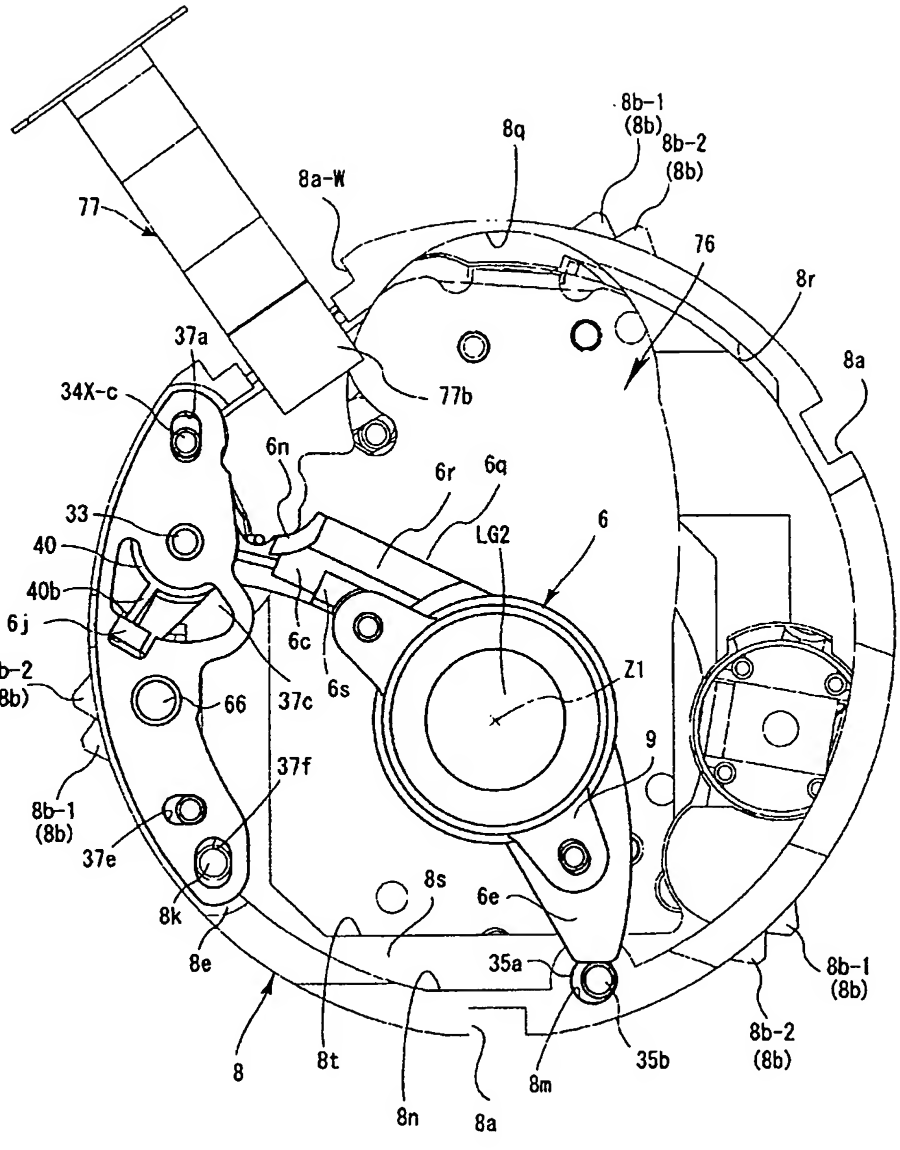
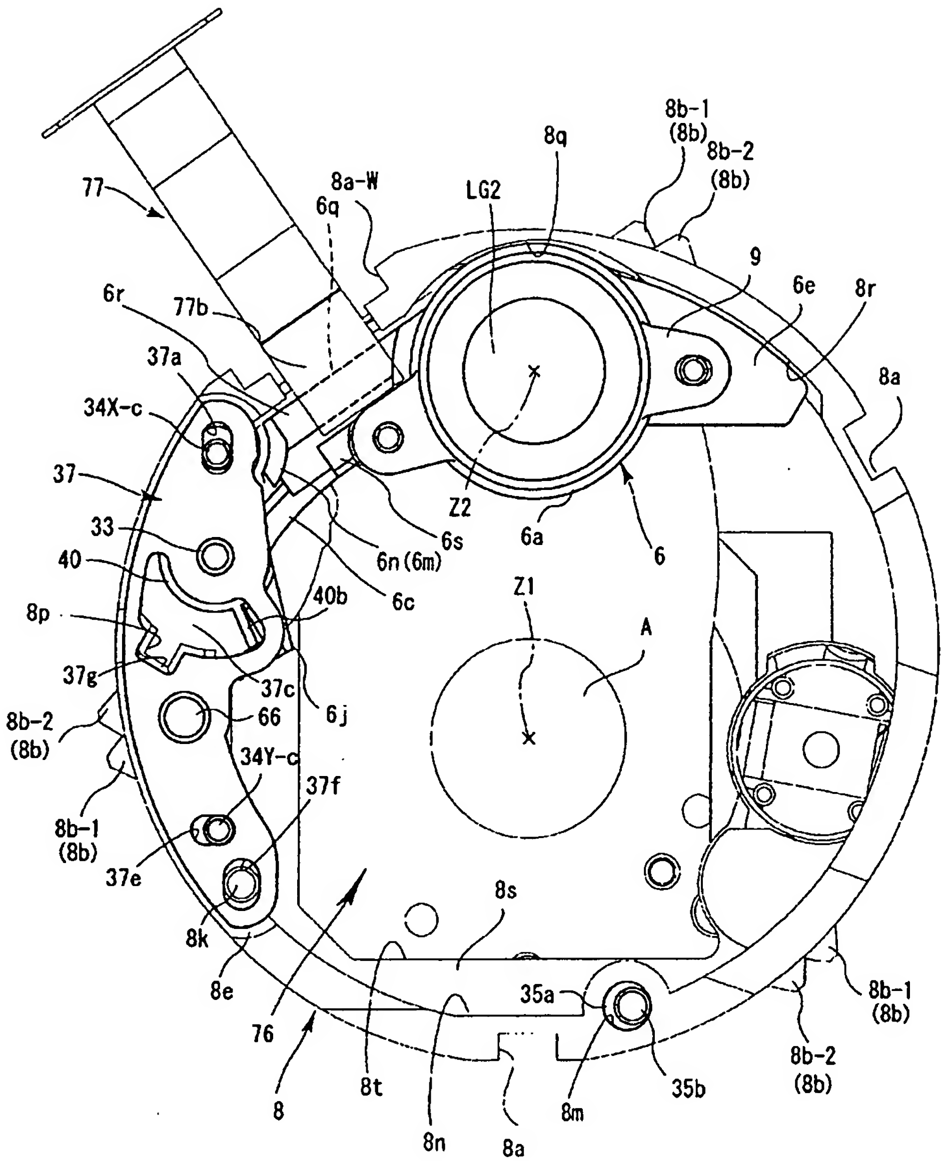

8b-1
(8b)
8q
8b-2
(8b)
8a-W
77
76
8r
8a
77b
37a
34X-c
6n
6r
6q
33
LG2
6
40
40b
6j
6c
6s
8b-2
(8b)
66
37c
Z1
9
37f
8b-1
(8b)
37e
8s
6e
8k
35a
8b-1
(8b)
8e
8b-2
(8b)
8
8t
8m
35b
8n
8a

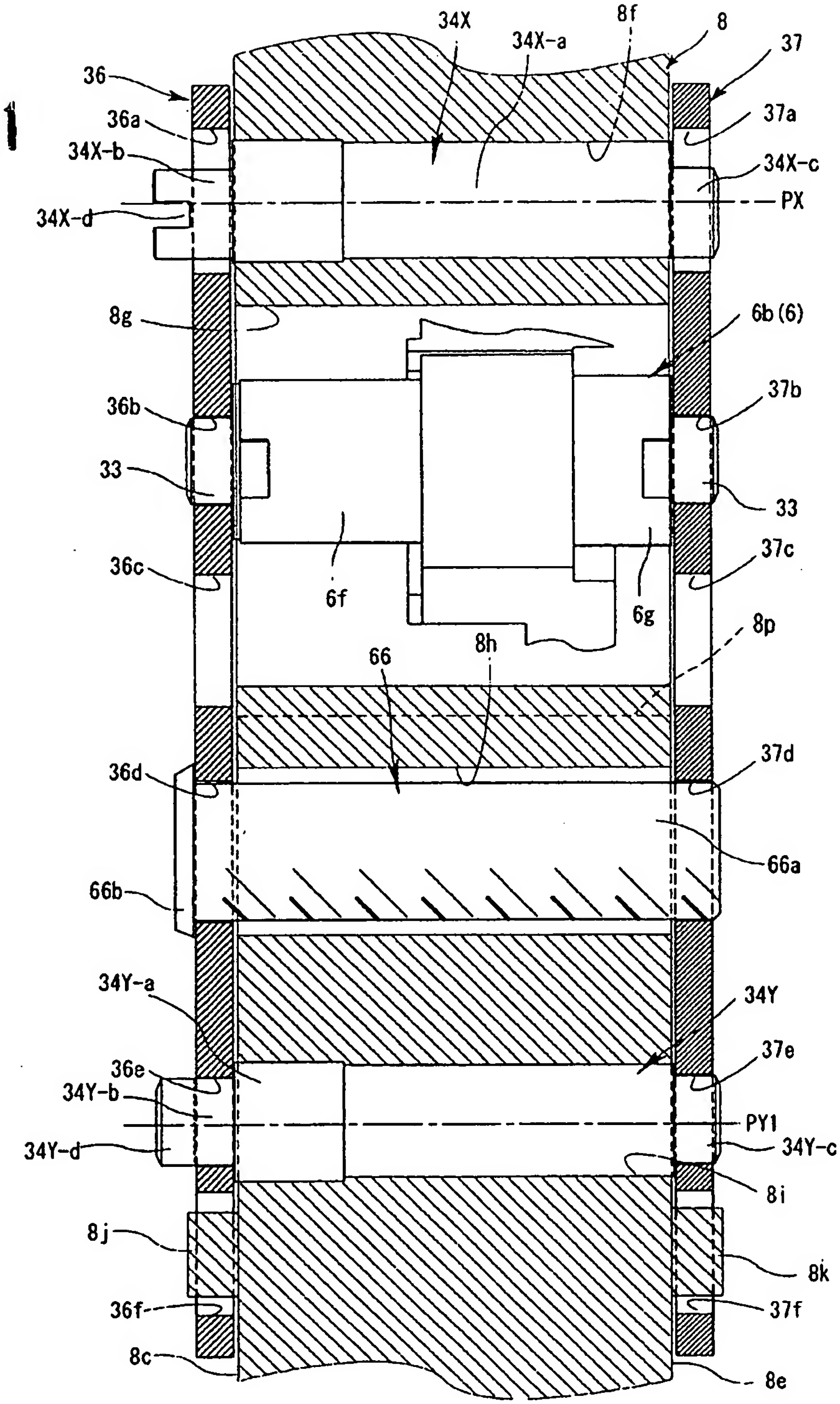
Fig. 29



77
77b
6r
37a
34X-c
37
33
40
8p
37g
8b-2
(8b)
8b-1
(8b)
37e
8k
8e
76
8
8t
8n
8a
8m
35b
35a
8s
37f
34Y-c
66
37c
6j
40b
6c
6n (6m)
6s
Z2
6a
6
6q
8a-W
LG2
8q
8b-1
(8b)
8b-2
(8b)
9
6e
8r
8a
Z1
A
8b-1
(8b)
8b-2
(8b)

Fig.30

Fig.31



34X
34X-a
8f
8
37
36
36a
37a
34X-b
34X-c
34X-d
PX
8g
6b(6)
36b
37b
33
33
36c
37c
6f
6g
8p
66
8h
36d
37d
66a
66b
34Y-a
34Y
37e
36e
34Y-b
PY1
34Y-d
34Y-c
8i
8j
8k
36f
37f
8c
8e

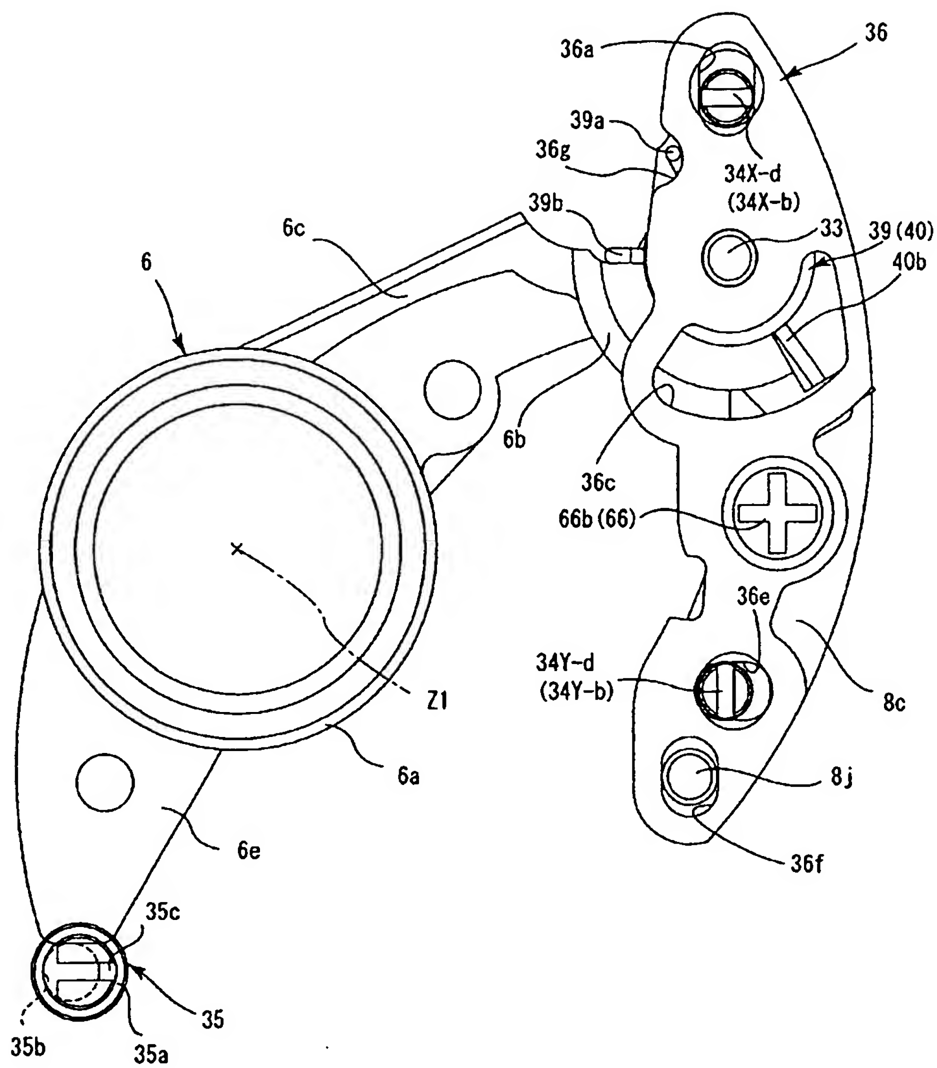
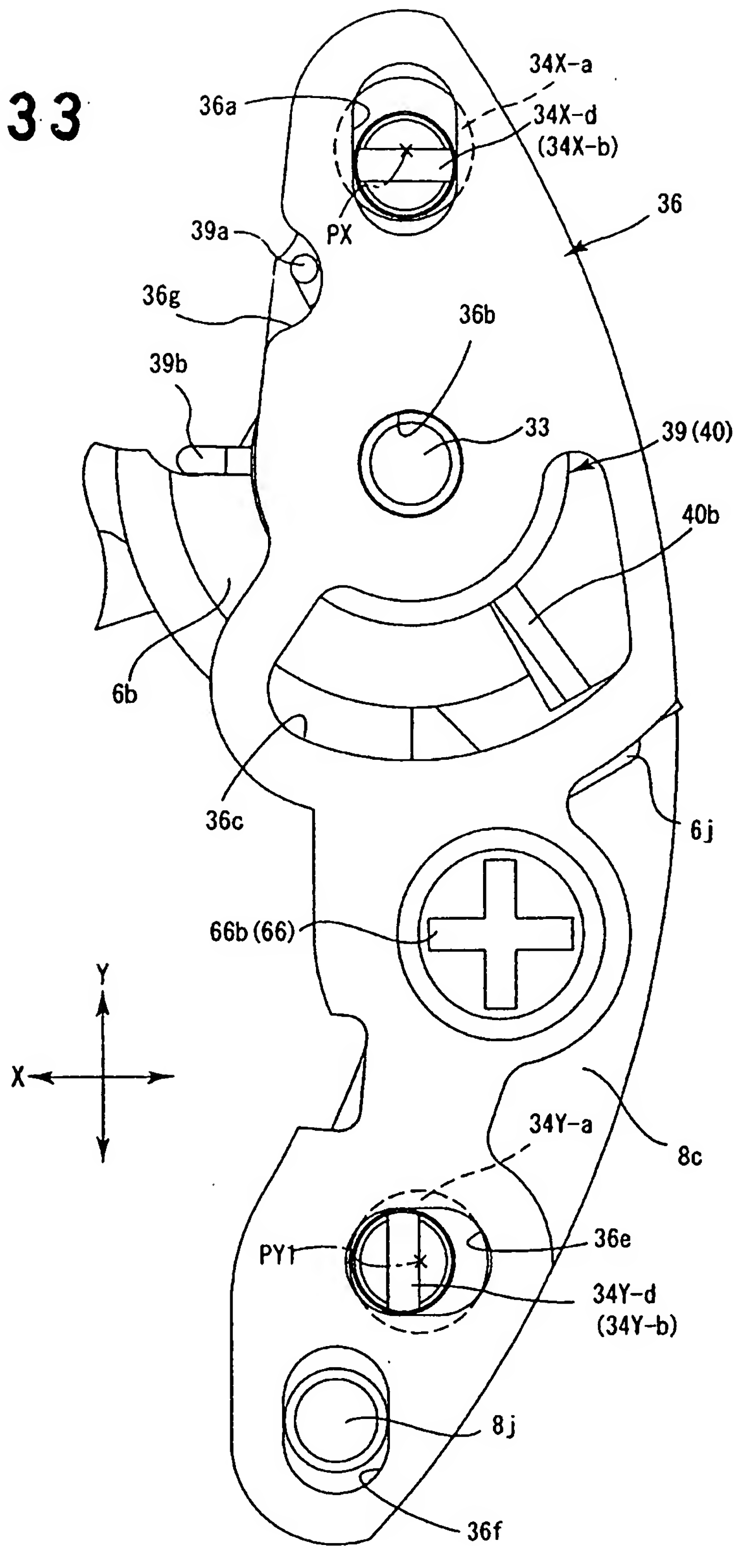

36a
36
39a
36g
34X-d
(34X-b)
39b
6c
33
39 (40)
40b
6
6b
36c
66b (66)
36e
34Y-d
(34Y-b)
8c
Z1
6a
8j
6e
36f
35c
35
35b
35a

Fig.32

Fig. 33



34X-a
36a
34X-d
(34X-b)
36
39a
PX
36g
36b
39b
33
39(40)
40b
6b
36c
6j
66b(66)
Y
X
34Y-a
8c
36e
PY1
34Y-d
(34Y-b)
8j
36f

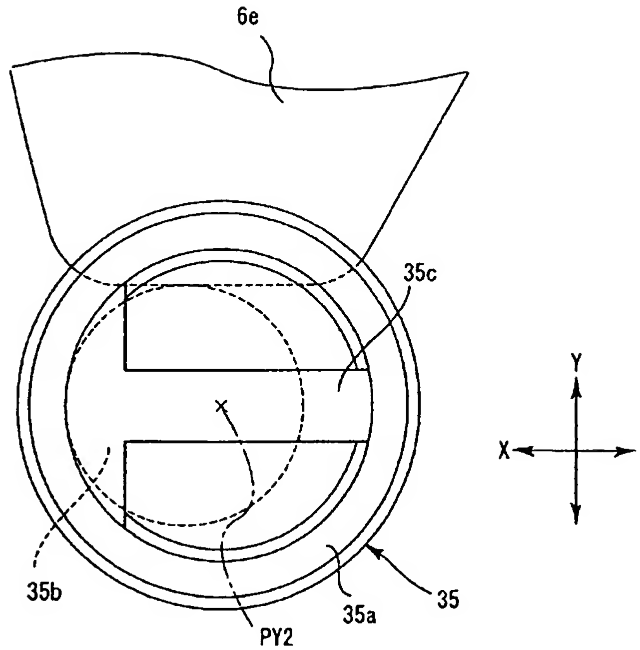
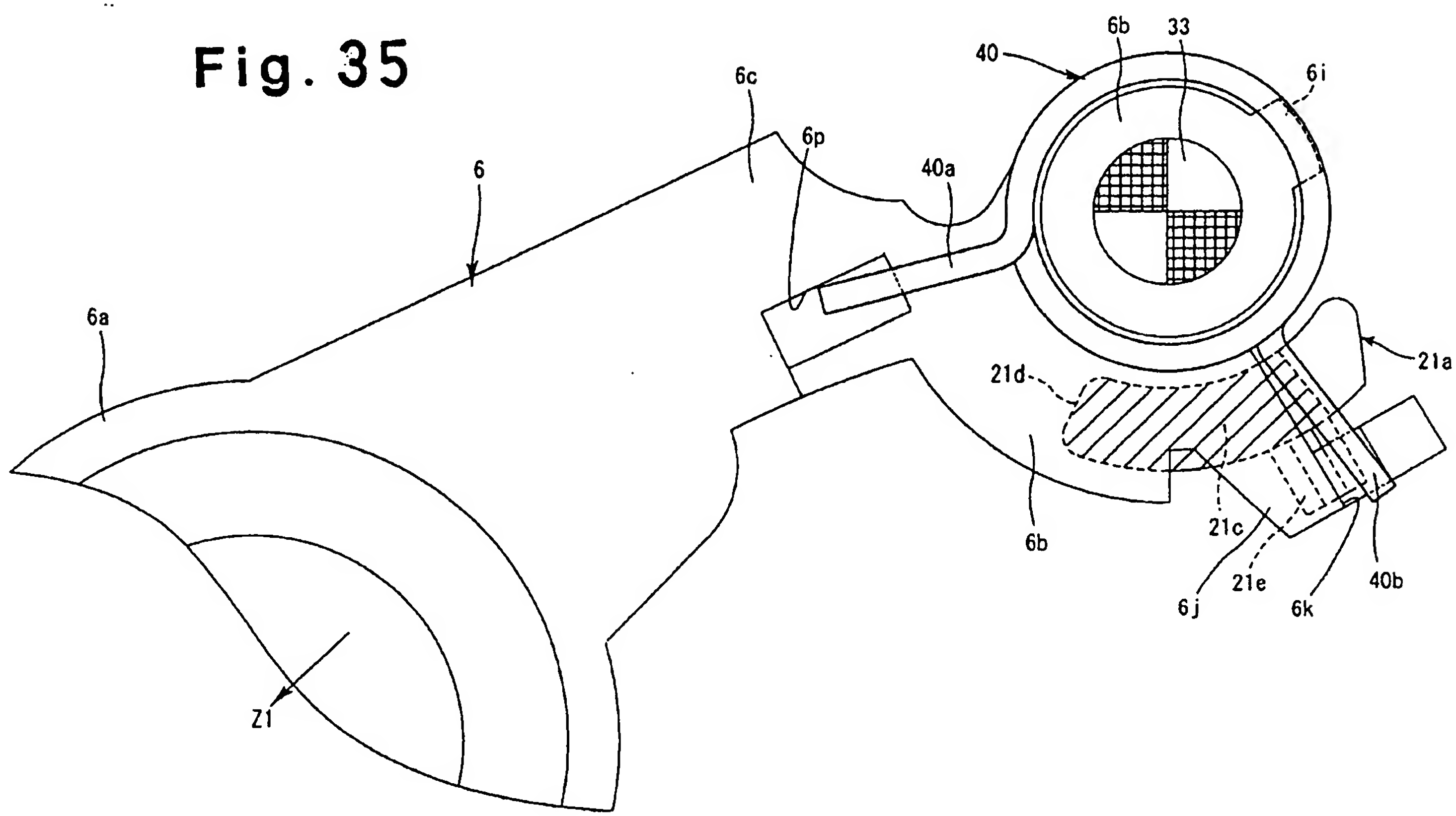


Fig. 34

Fig. 35



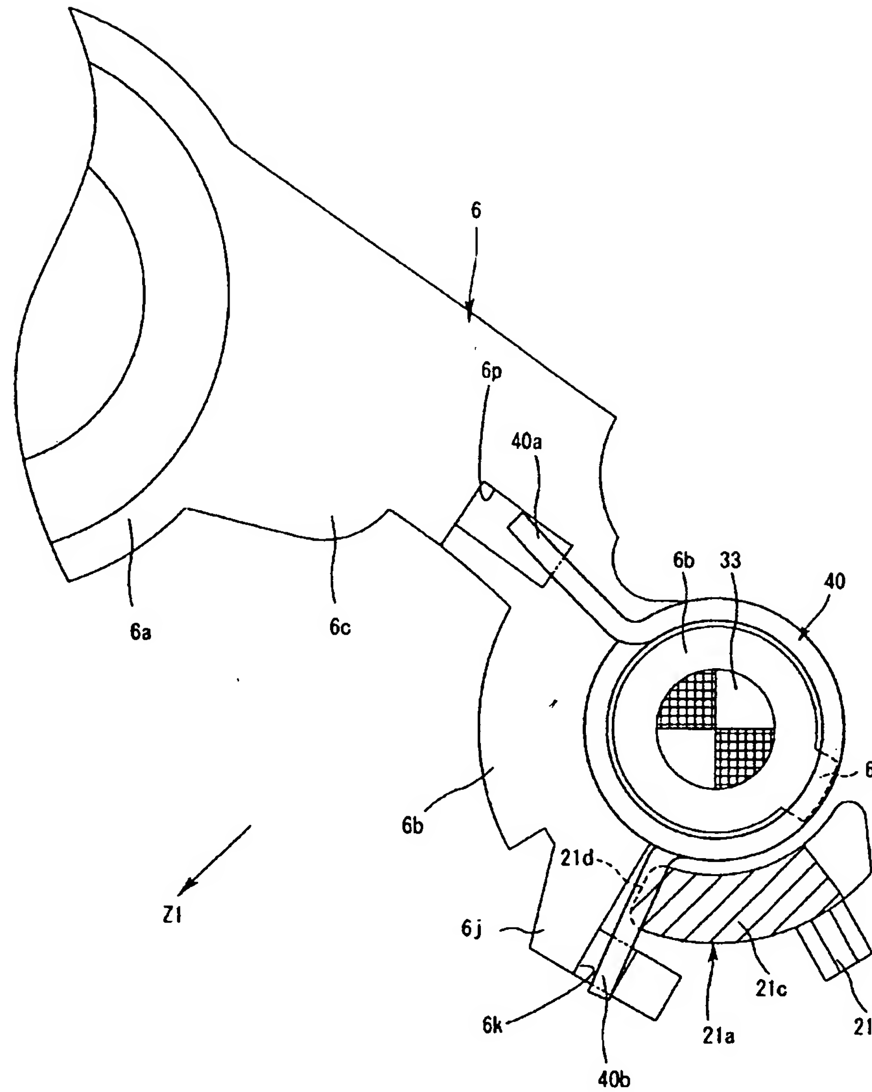


Fig.36

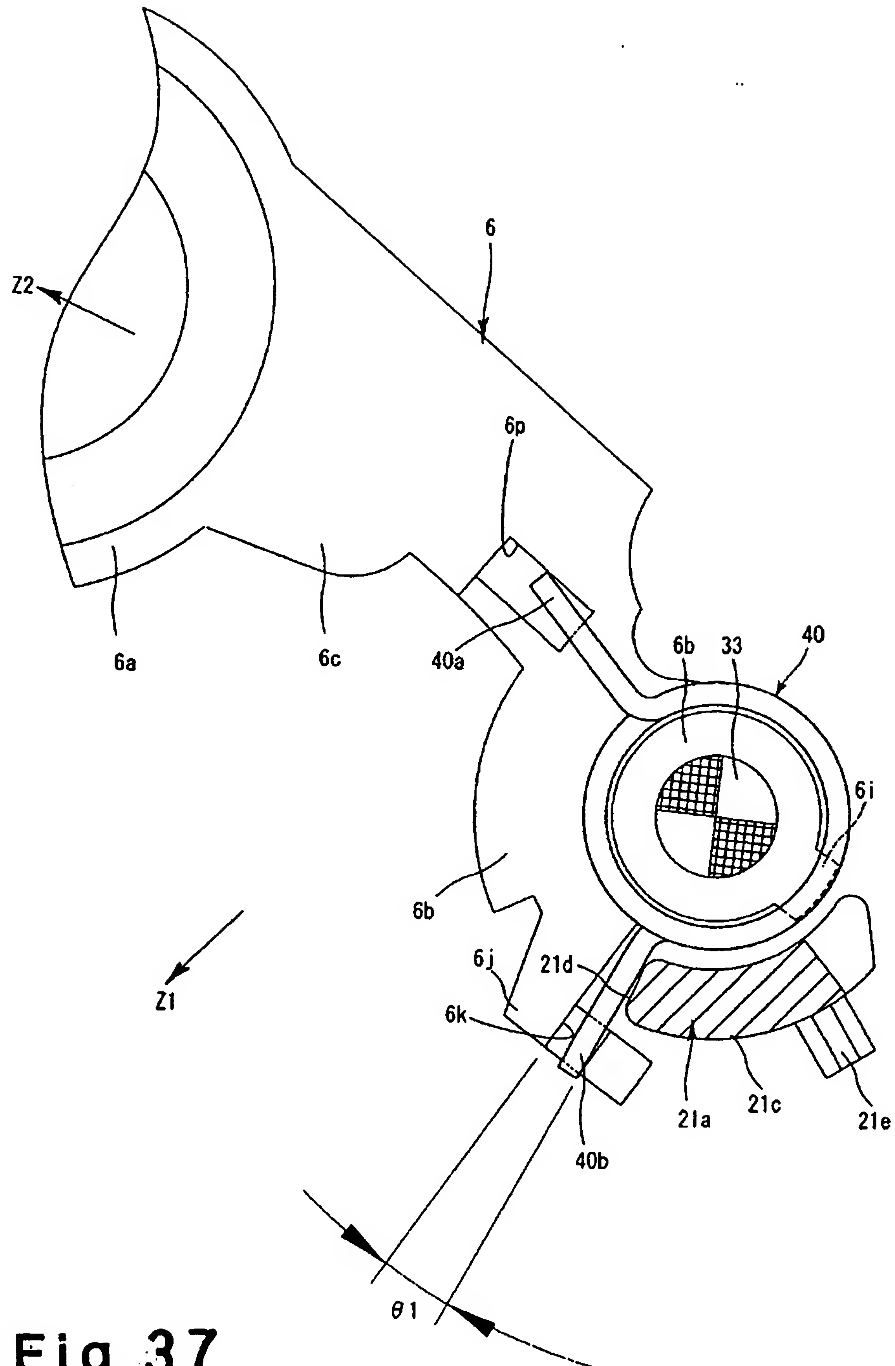


Fig.37

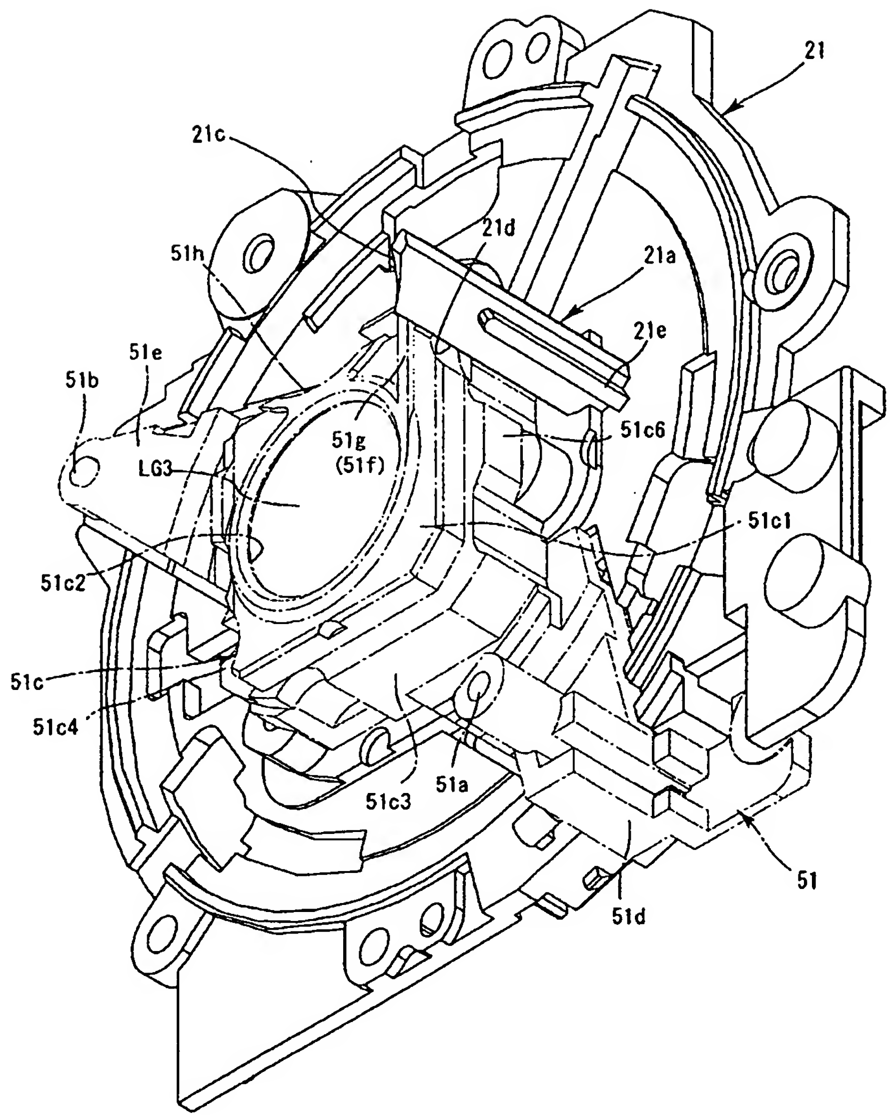
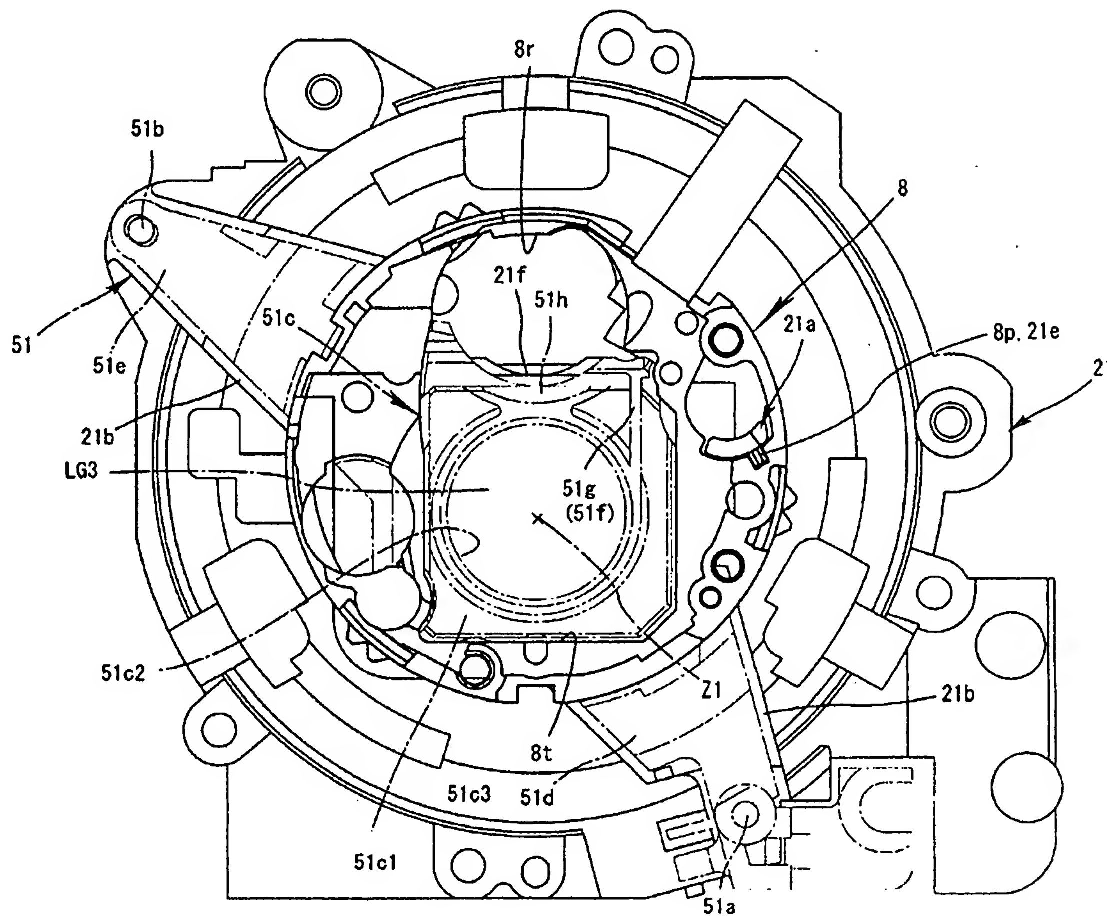
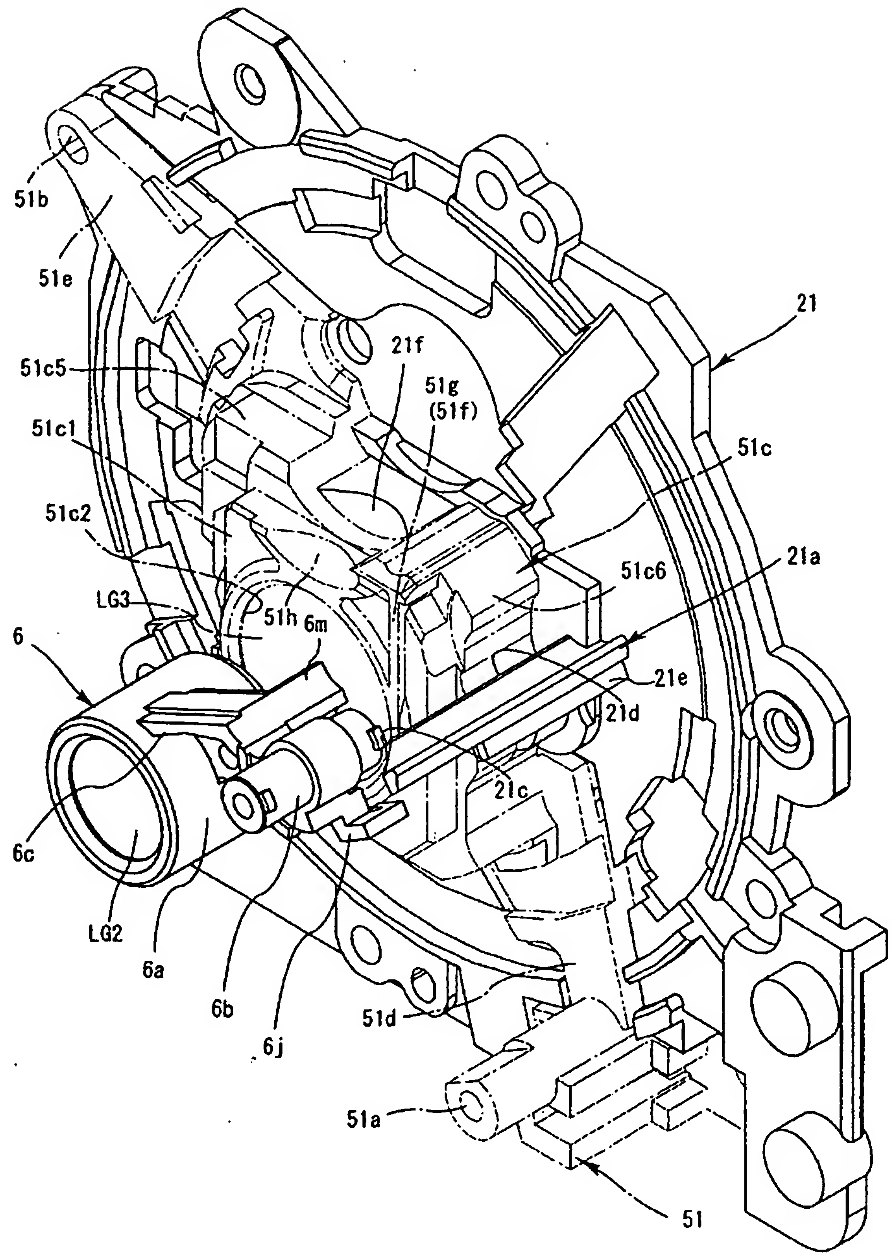

21
21c
21d
21a
21e
51h
51e
51b
LG3
51g
(51f)
51c6
51c1
51c2
51c
51c4
51c3
51a
51
51d

Fig.38

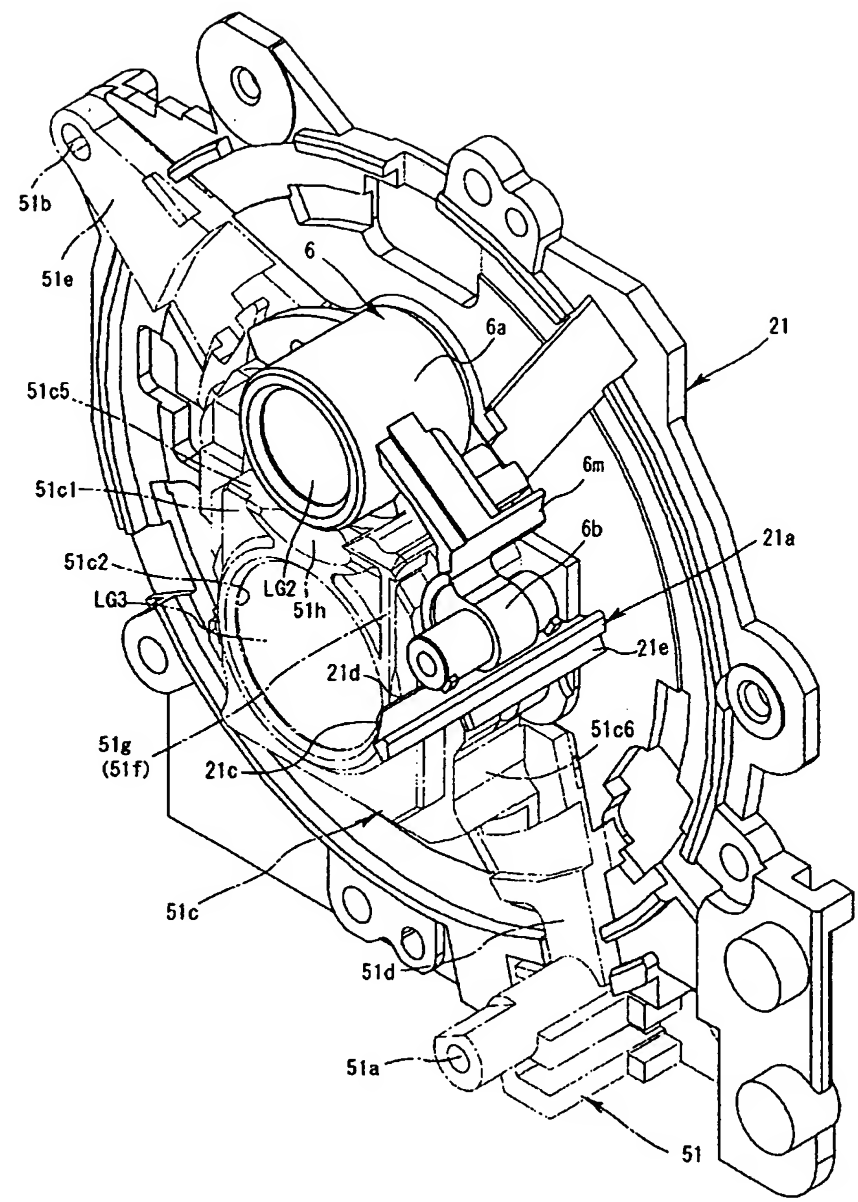
Fig.39


51b
8r
8
21f
51h
21a
8p. 21e
21
51c
51
51e
21b
LG3
51g
(51f)
51c2
Z1
21b
8t
51c3
51d
51c1
51a



51b
51e
21
51c5
21f
51g
(51f)
51c1
51c
51c2
21a
51c6
LG3
51h
6m
6
21e
21d
21c
6c
LG2
6a
6b
51d
6j
51a
51

Fig.40



51b
51e
6
6a
21
51c5
6m
51c1
6b
21a
51c2
LG2
51h
LG3
21e
21d
51g
(51f)
21c
51c6
51c
51d
51a
51

Fig.41

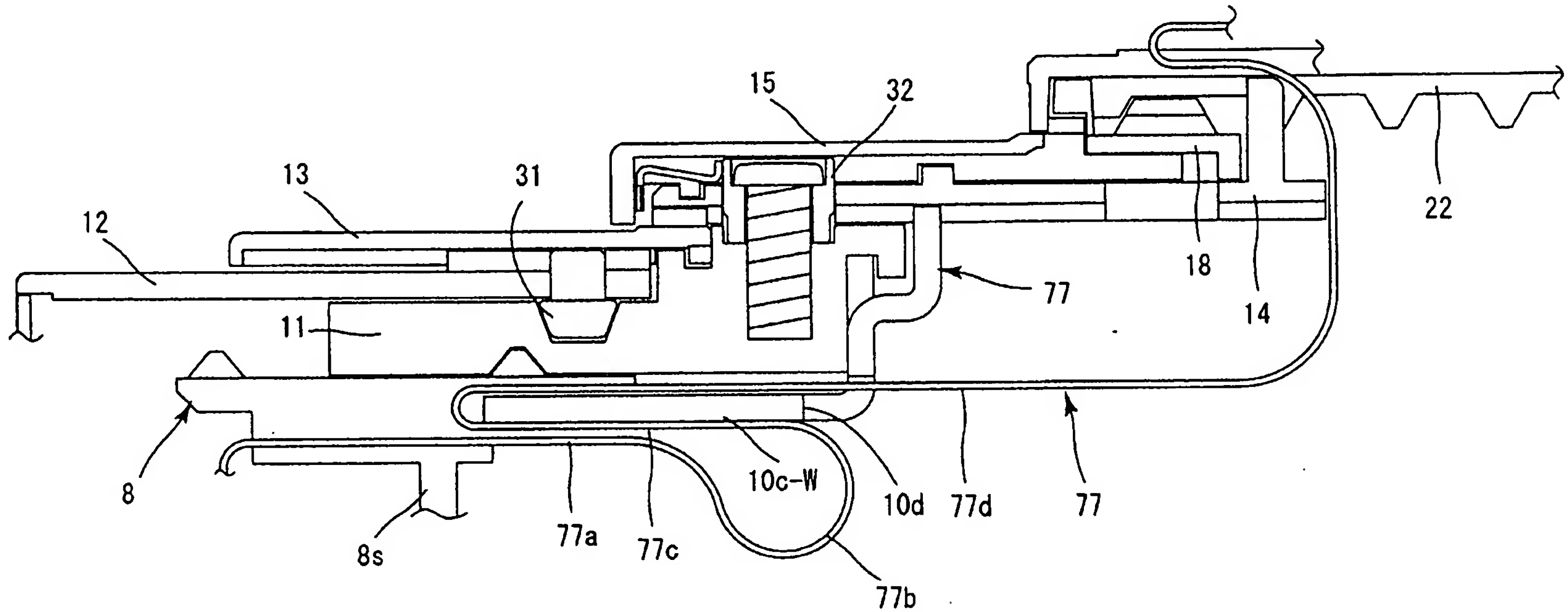


Fig.42

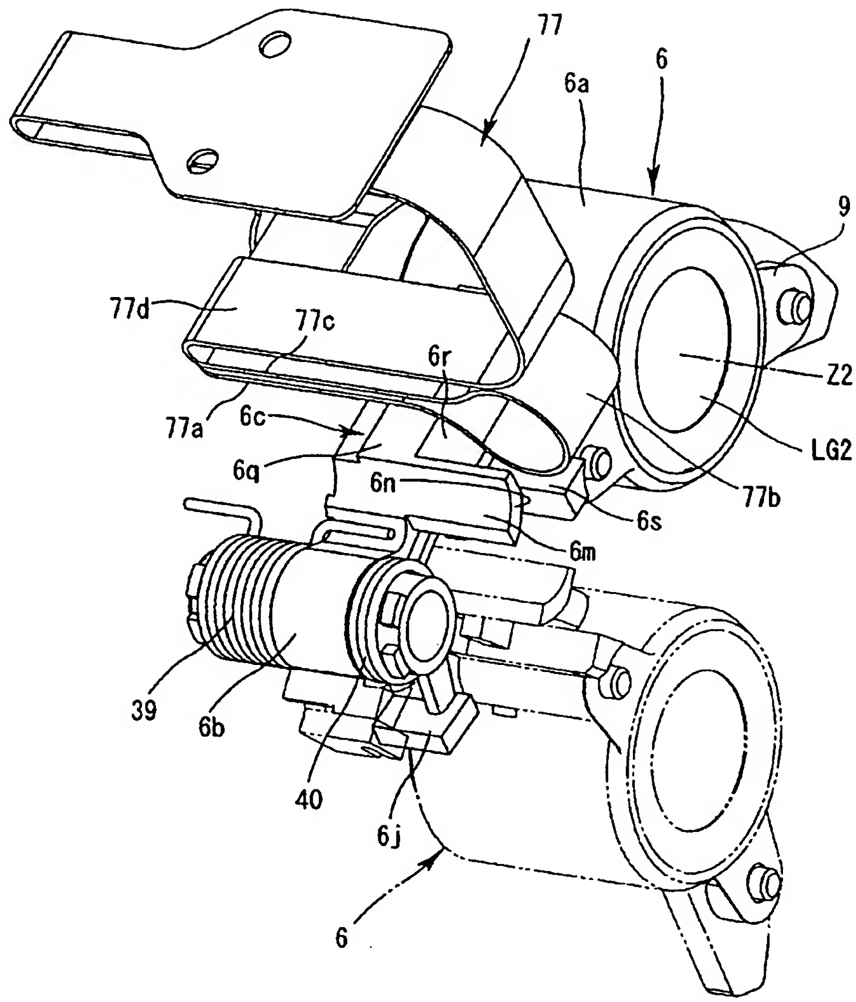
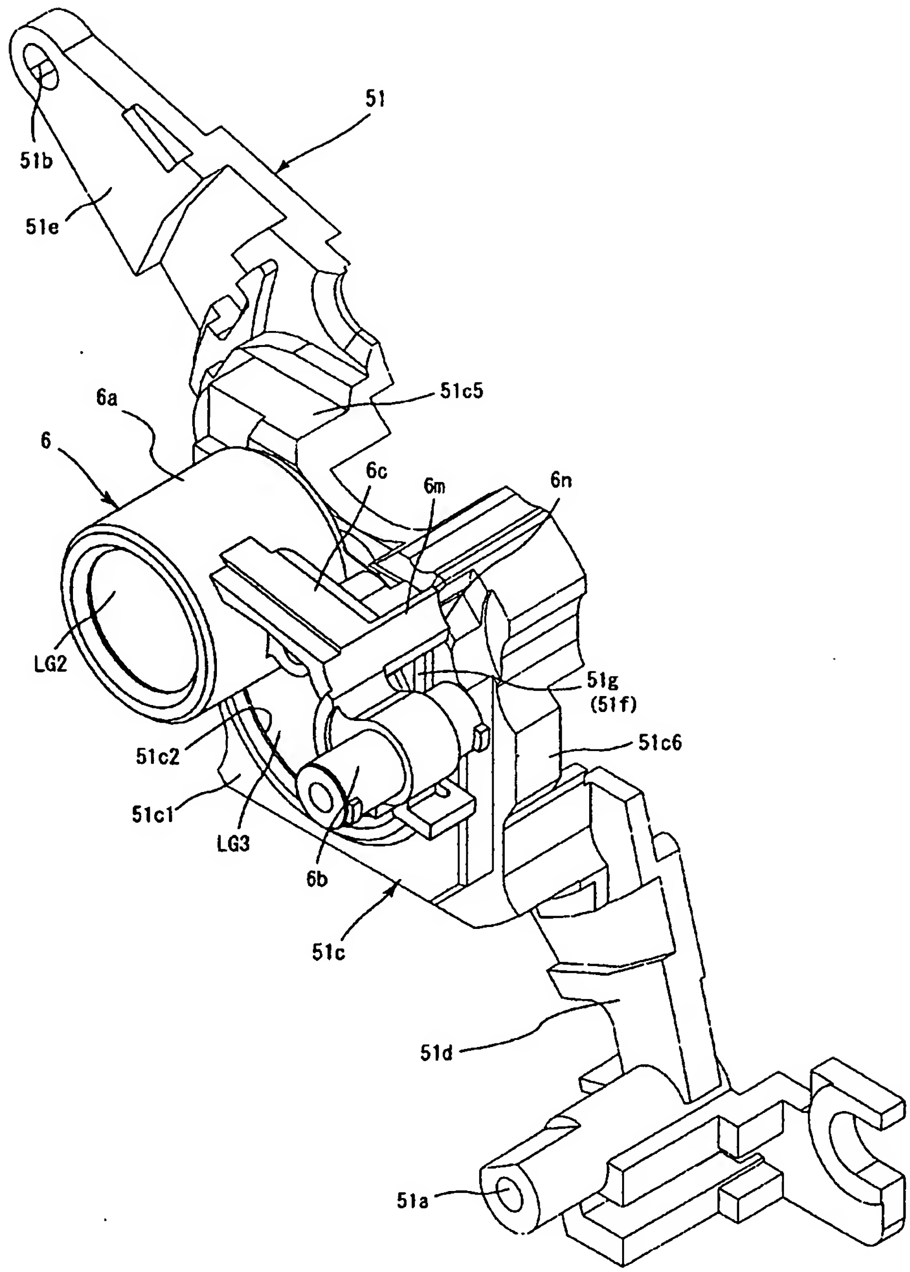


Fig. 43



51
51b
51e
51c5
6a
6
6c
6m
6n
LG2
51g
(51f)
51c6
51c2
51c1
LG3
6b
51c
51d
51a

Fig.44

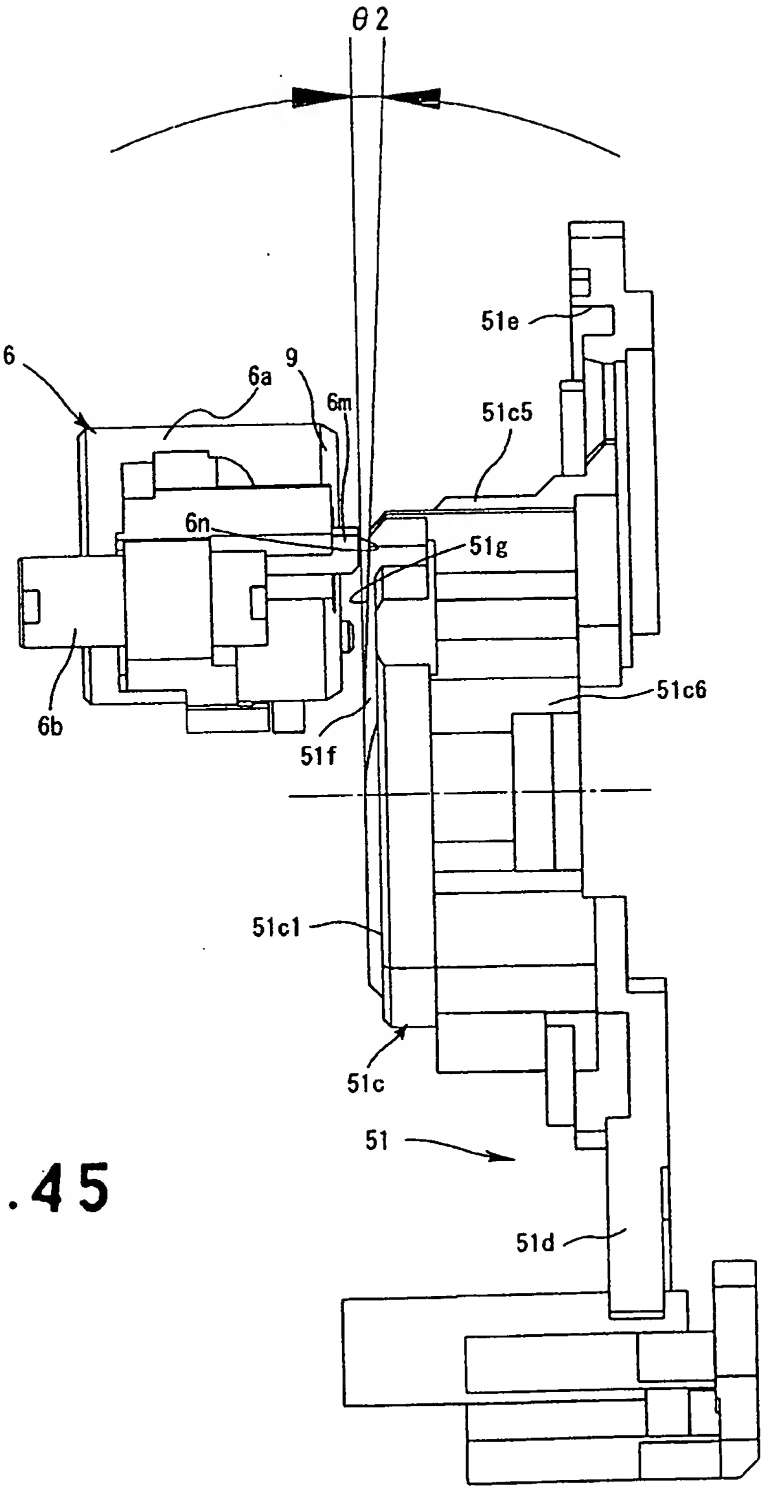


Fig.45

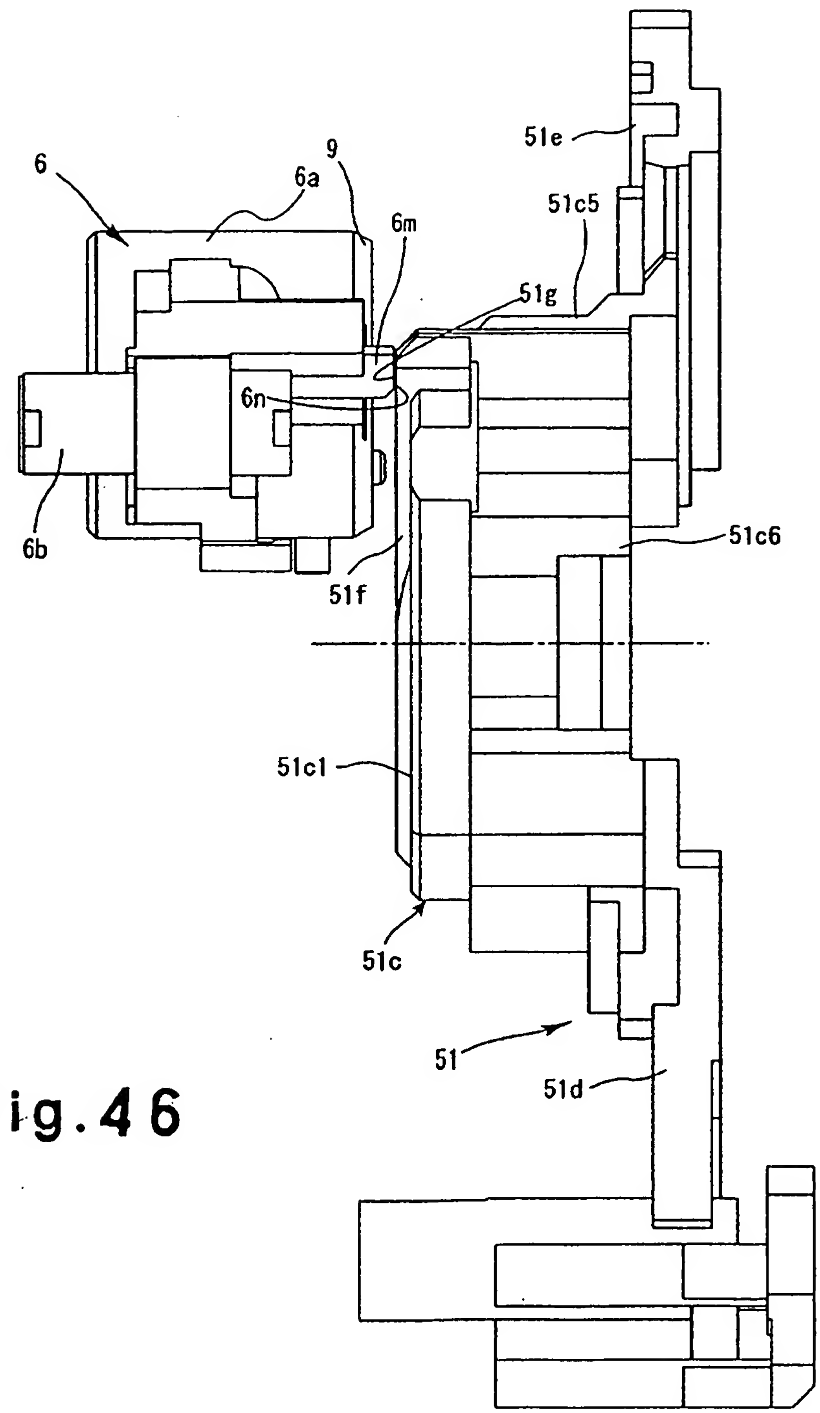


Fig.46

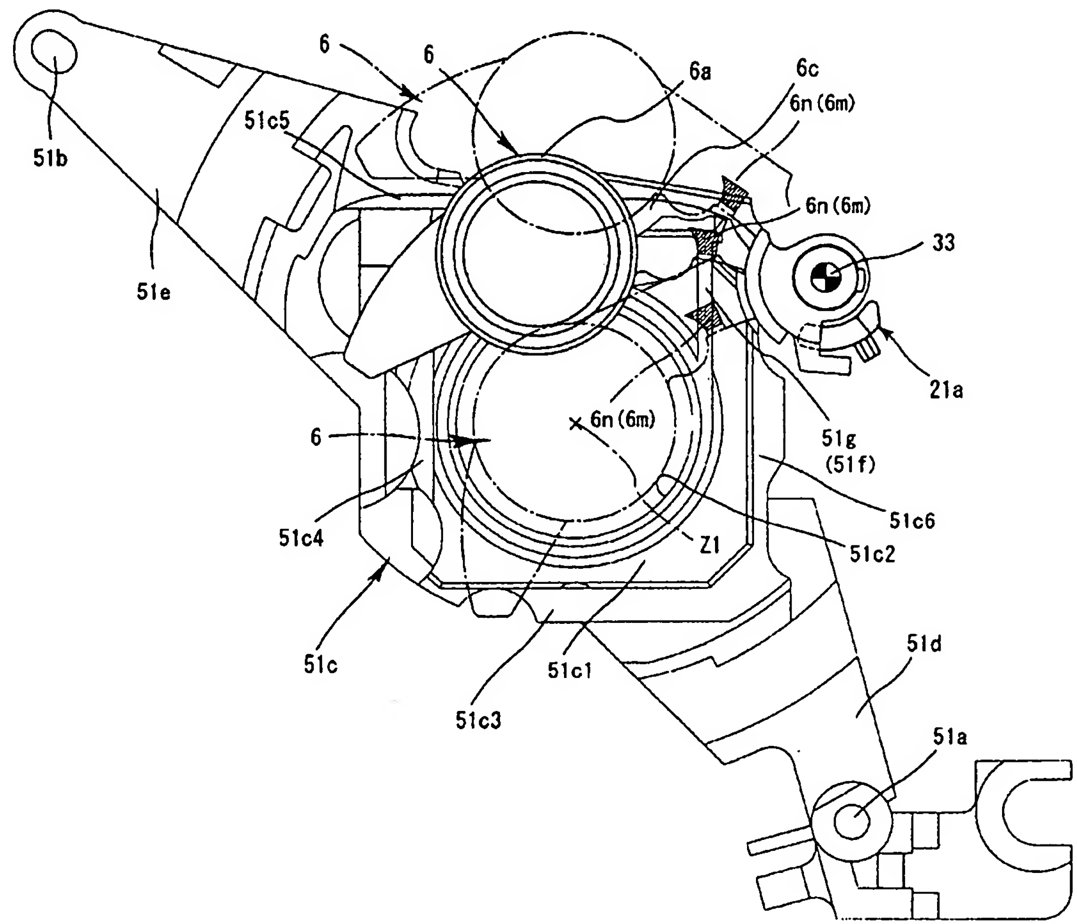

6
6
6a
6c
6n (6m)
6n (6m)
33
21a
51b
51c5
51e
6n (6m)
6
51g
(51f)
51c6
51c4
51c2
Z1
51c
51c1
51c3
51d
51a

Fig. 47

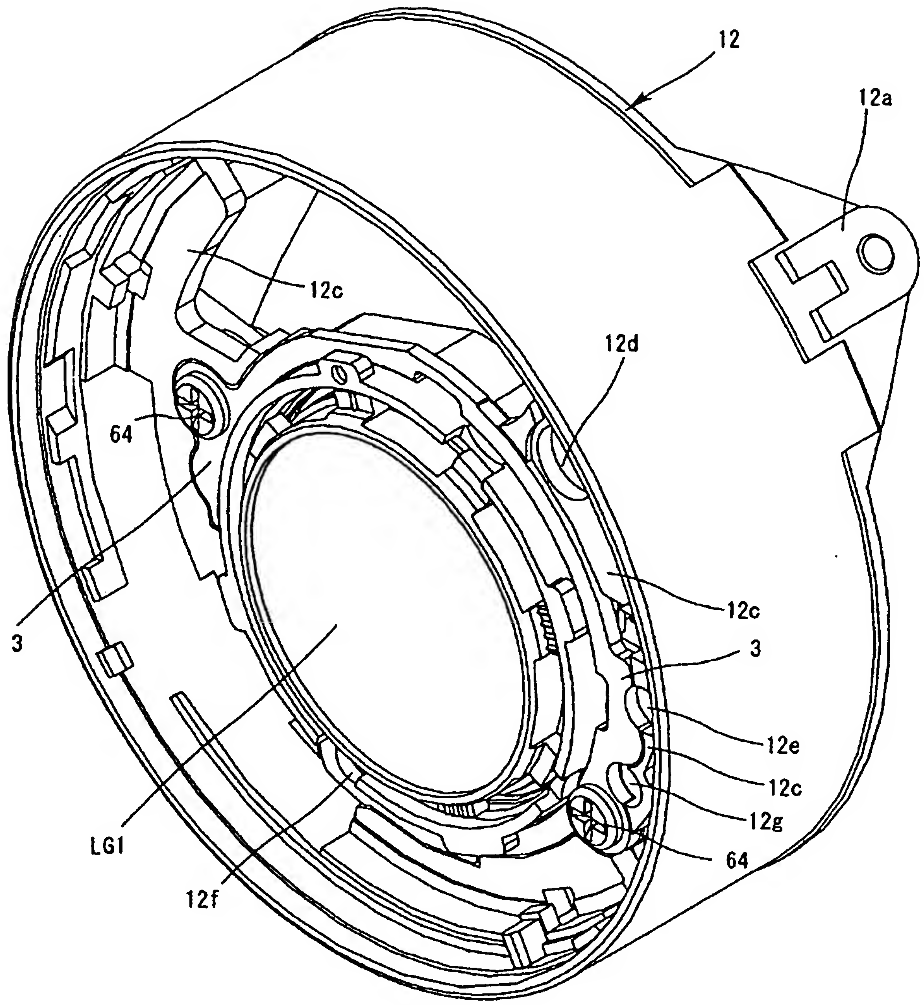


Fig. 48

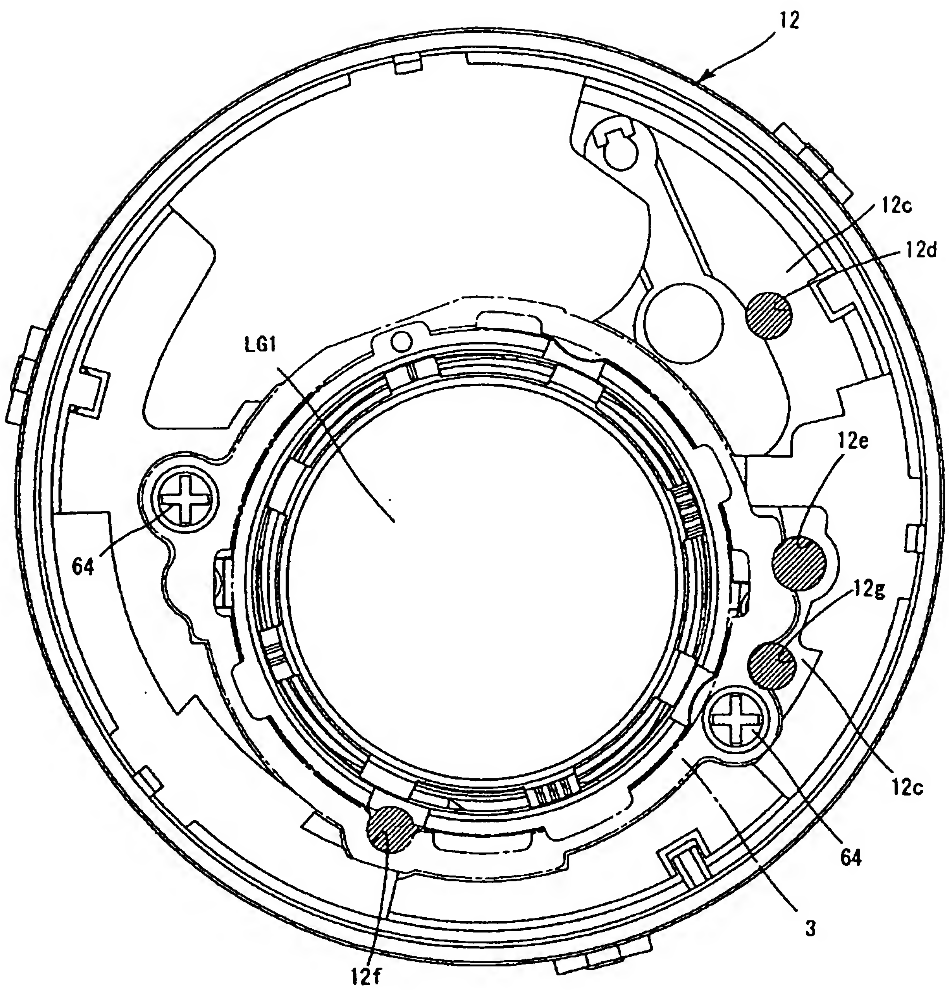


Fig.49

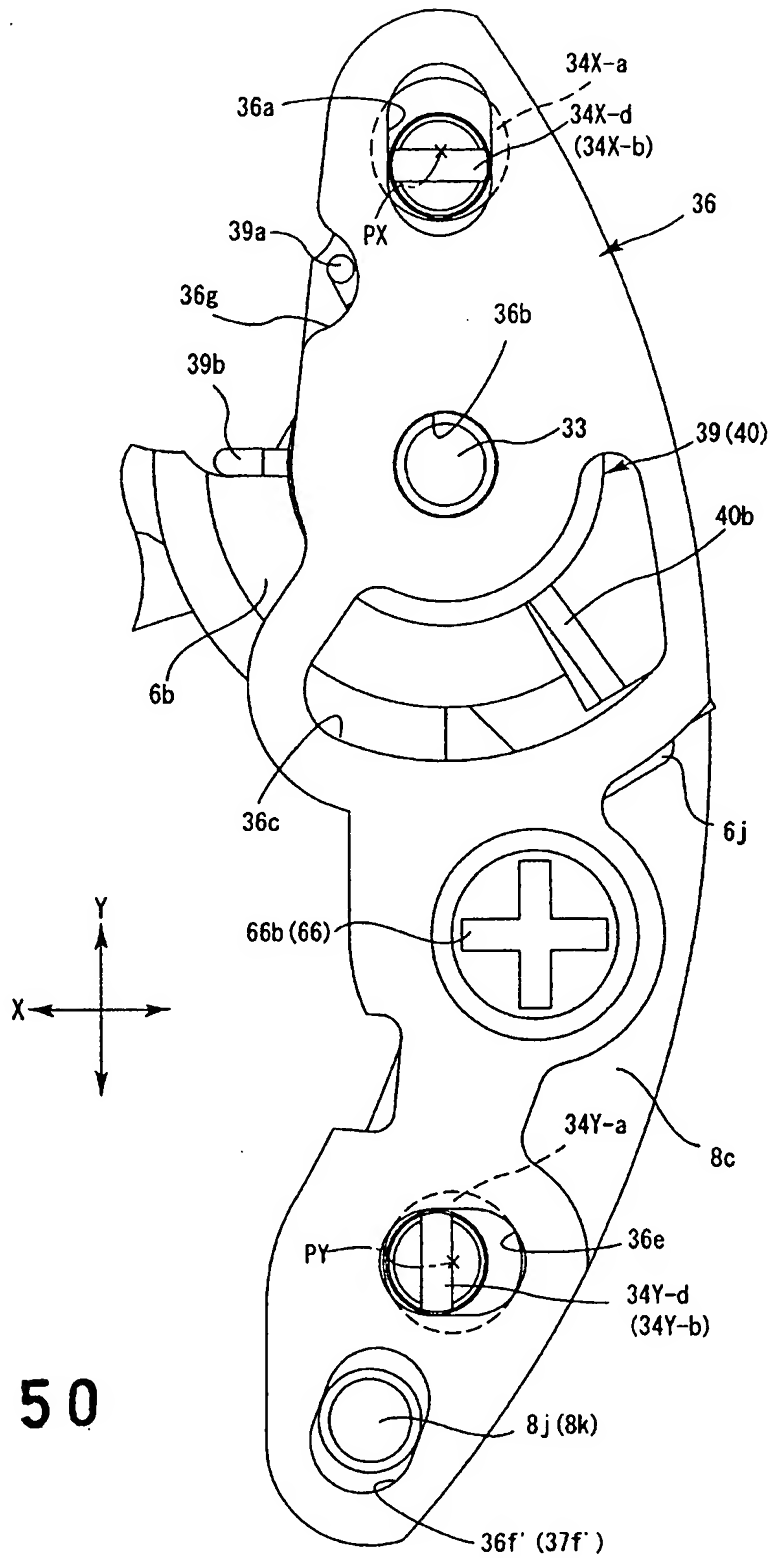

34X-a
36a
34X-d
(34X-b)
36
PX
39a
36g
36b
39b
33
39(40)
40b
6b
36c
6j
Y
66b(66)
X
34Y-a
8c
36e
PY
34Y-d
(34Y-b)
8j(8k)
36f' (37f')

Fig. 50

Fig.51

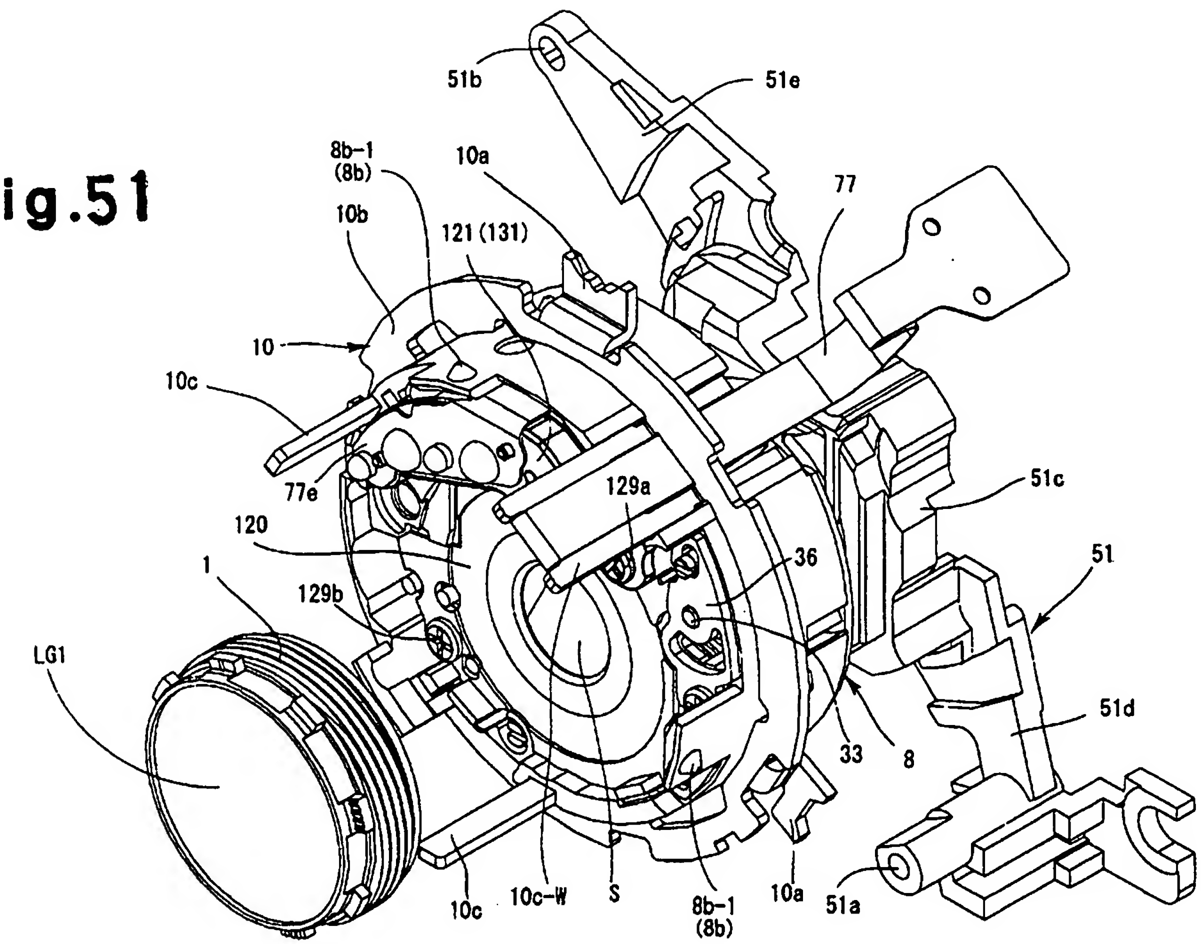
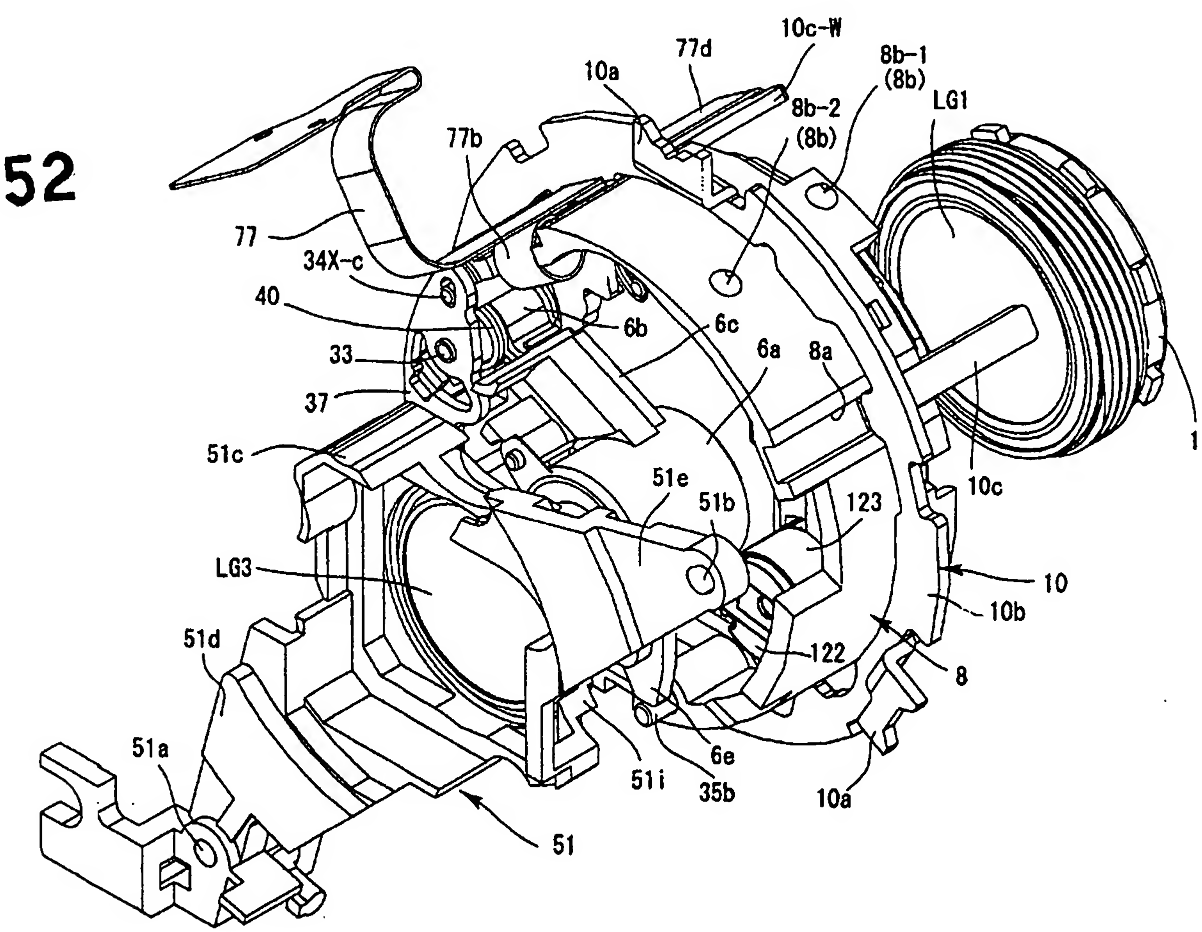
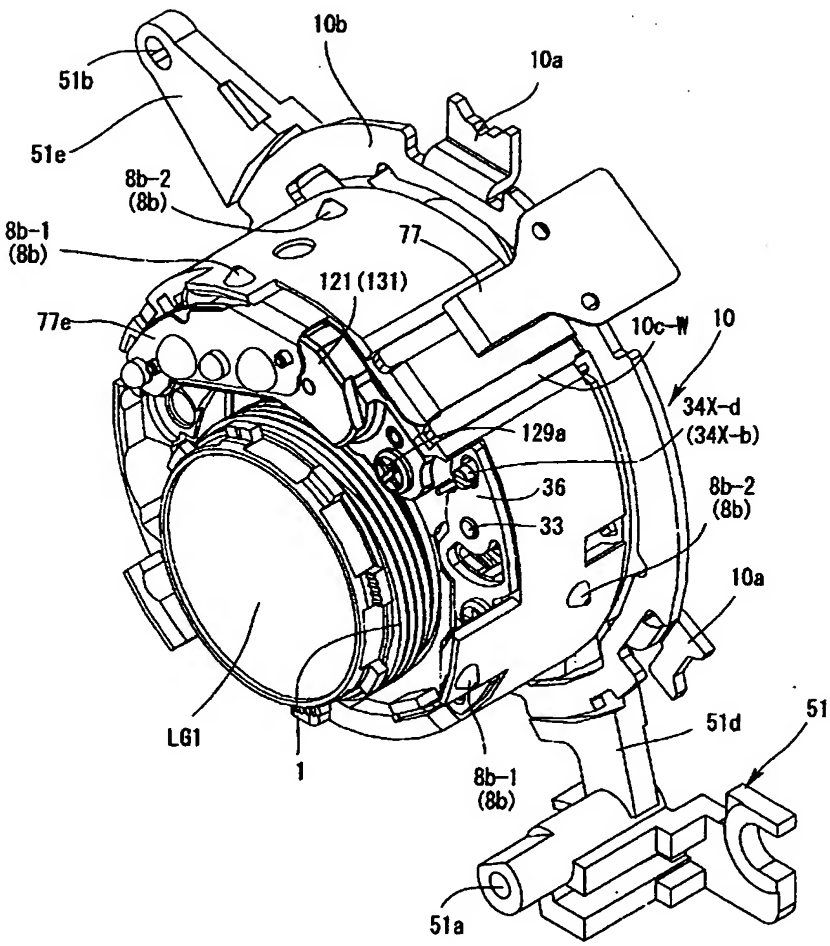

51b
51e
8b-1
(8b)
10a
77
10b
121 (131)
10
10c
77e
129a
120
36
51c
51
1
129b
LG1
51d
33
8
10c
10c-W
S
8b-1
(8b)
10a
51a

Fig.52



77
77b
77d
10a
10c-W
8b-1
(8b)
8b-2
(8b)
LG1
34X-c
40
6b
6c
6a
8a
33
37
1
51c
51e
51b
123
10c
LG3
10
10b
51d
122
8
51a
6e
51i
35b
10a
51



10b
10a
51b
51e
8b-2
(8b)
8b-1
(8b)
77
77e
121 (131)
10c-W
10
34X-d
(34X-b)
129a
36
33
8b-2
(8b)
10a
LG1
1
8b-1
(8b)
51d
51
51a

Fig.53

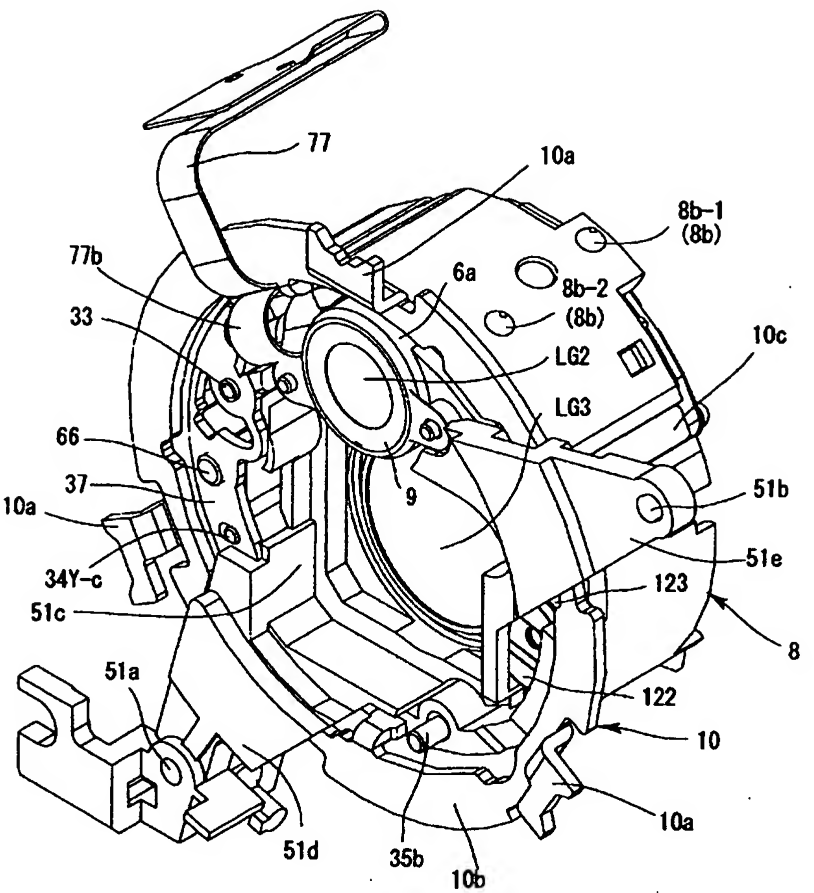

77
10a
8b-1
(8b)
77b
6a
8b-2
(8b)
33
10c
LG2
LG3
66
9
51b
37
10a
34Y-c
51e
123
51c
8
51a
122
10
10a
51d
35b
10b

Fig.54

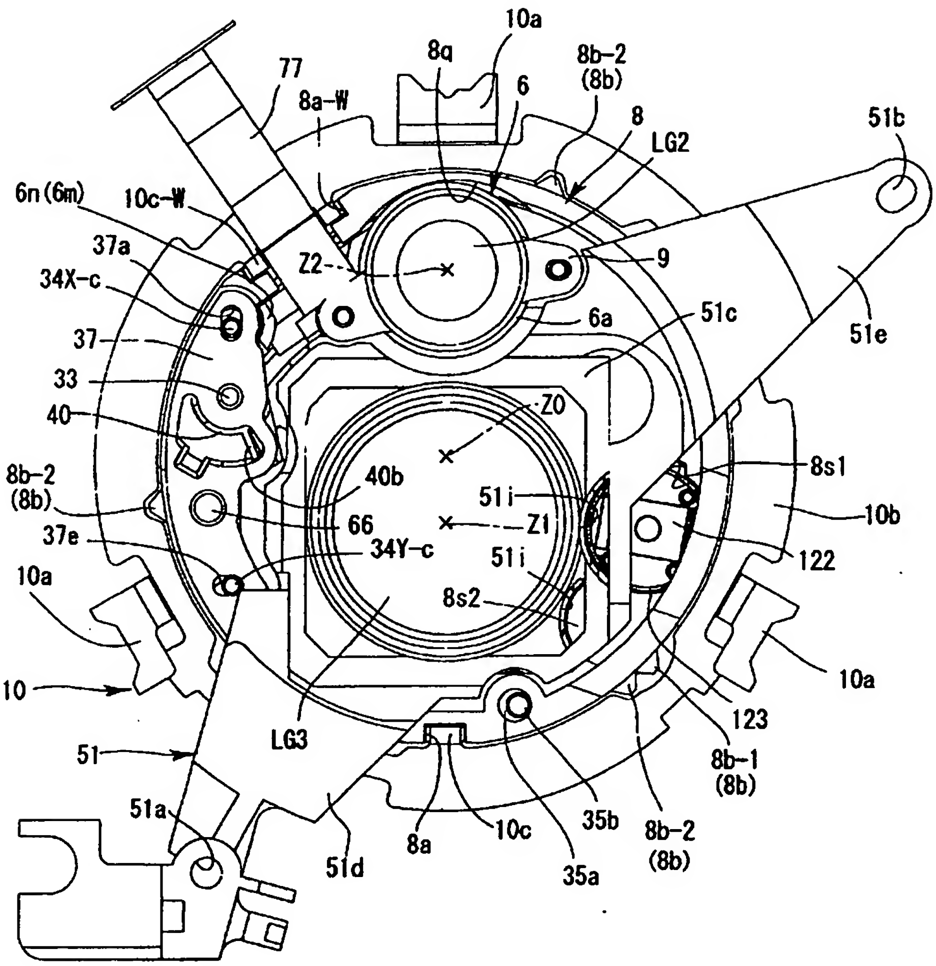

10a
8q
6
8b-2
(8b)
8
LG2
51b
77
8a-W
6n(6m)
10c-W
Z2
9
37a
34X-c
6a
51c
51e
37
33
Z0
40
40b
8s1
8b-2
(8b)
51i
Z1
10b
66
37e
34Y-c
51i
122
10a
8s2
10a
10
123
LG3
51
8b-1
(8b)
51a
35b
8b-2
(8b)
10c
8a
51d
35a

Fig.55

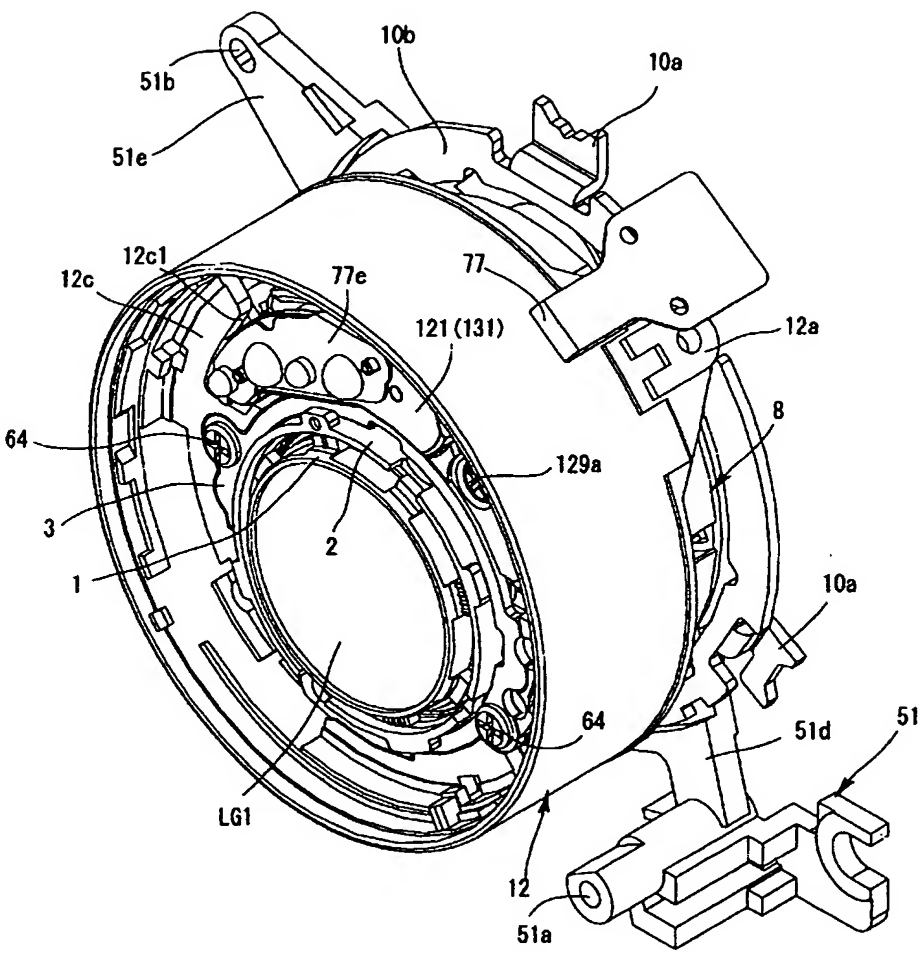

10b
10a
51b
51e
12c1
77e
12c
77
121 (131)
12a
8
64
129a
3
2
1
10a
64
51d
51
LG1
12
51a

Fig.56

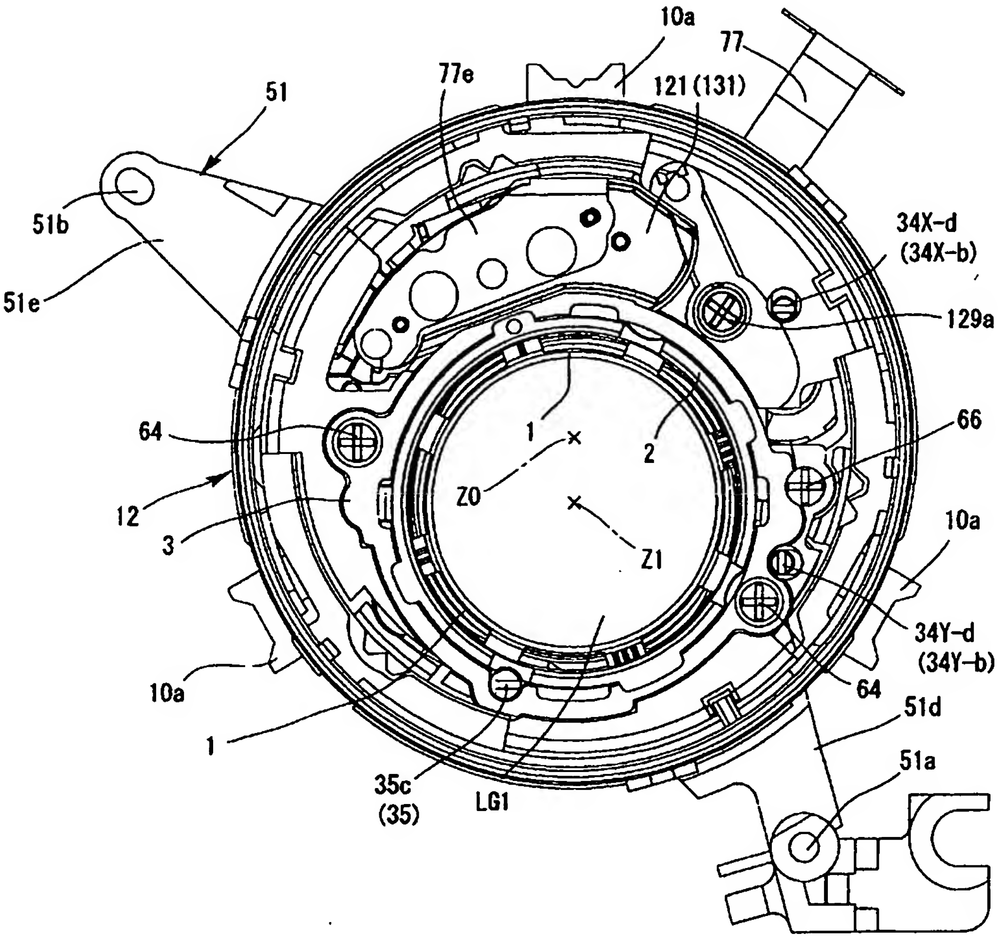
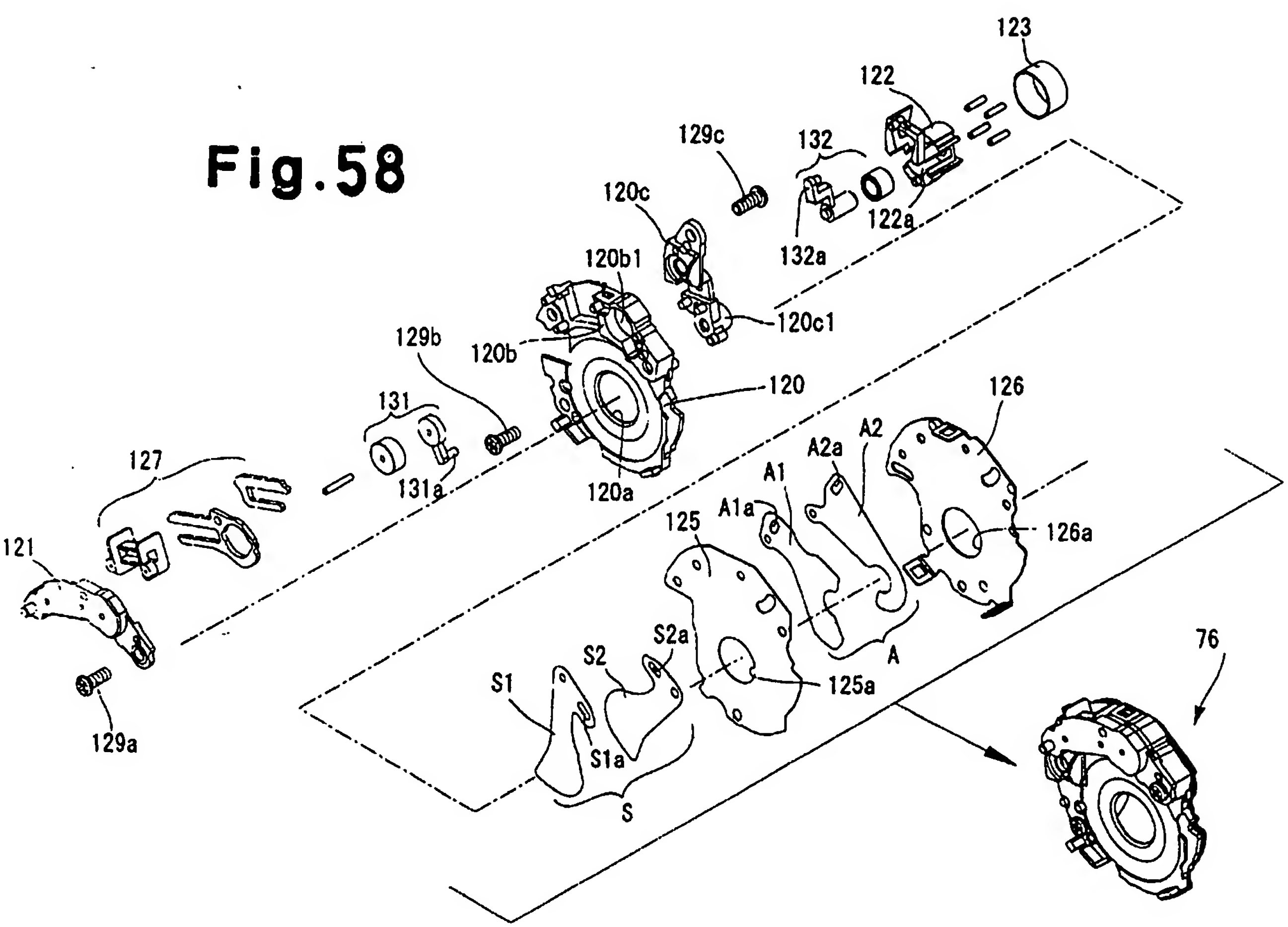

10a
77
77e
121 (131)
51
51b
51e
34X-d
(34X-b)
129a
64
1
66
2
12
Z0
3
Z1
10a
34Y-d
(34Y-b)
10a
64
51d
1
51a
35c
(35)
LG1

Fig.57

Fig.58


123
122
122a
132
132a
129c
120c
120c1
120b1
120b
120
129b
131
131a
120a
127
121
129a
126
126a
A2
A2a
A1
A1a
A
125
125a
S2a
S2
S1
S1a
S
76